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Contents

Editorial

ELECTRONIC PUBLISHING

This month sees the final part of our *Technology Timelines* series. Amongst myriad other topics, mention is made of the impact of “new technology” on publishing and printing. As we point out, it was thought that radio and later television would have an impact on conventional publishing and that magazines and books would gradually disappear. That, of course, proved not to be the case and, in fact, if you look at the magazines and books that are spin-offs from various “electronic media” programs, plus, of course, all the listings information, it is likely that the only impact these media have had on paper publishing is to increase its output. This may, however, not continue to be the case.

In our own small way we are at the forefront of publishing on the web – there are still very few printed magazines that you can also download directly from a web site – but far from detracting from the published issue it has actually helped to increase sales of the printed edition. While *EPE Online* is a great boon particularly to overseas readers on instant availability and price, a number of Online customers have gone on to additionally order printed copies – presumably because, as we note in this month’s *Technology Timelines* article, there is still something aesthetically pleasing about a printed publication.

With the development of display technology – like the electronic ink reported in *New Technology Update* in the April 2000 issue (incidentally, one reader questioned if this was an April Fool, we can assure you it was not, technology is often stranger than fiction these days) – how much longer will it be until E-books take over, or will we still prefer the feel of paper pages in our hands?

Sometimes much is made of the need to cut down trees to make magazines and books, but these days these trees are “harvested crops” as opposed to naturally growing forests. Thus it may be better for the environment, and for employment, that we produce paper rather than computers. As always, not every step forward is as good for the world at large as it may at first appear to be.

BACK ISSUES ON CD

Back issues of EPE Online are $5 US dollars. Quite a few readers email us to say that this isn’t a problem in the case of individual issues, but that they would very much like to purchase all of our back issues. So as of this month, you can now obtain some of our back issues on CD-ROM. Volume 1 of the new mini CDs (which run on any CD reader) containing back issues from Nov ’98 to June ’99 is now available and we hope to follow up with Volume 2 (July ’99 to Dec ’99) fairly soon.

Clive Maxfield & Alvin Brown

Next Month

PICGen FREQUENCY GENERATOR AND COUNTER

Combining the sophisticated features of a Maxim MAX038 waveform generator and a PIC16F877 microcontroller has resulted in a highly versatile and inexpensive workshop tool, whose facilities have hitherto been unattainable without considerable design complexity.

The MAX038 is a high-frequency precision function generator whose output is selectable to produce triangle, sine and square waveforms, within a wide operating frequency span of 0·1Hz to over 10MHz, split into eight overlapping ranges. Range and waveform selection are performed by the PIC16F877 in response to pushbutton switch controls. Frequency is fully variable within the selected range by means of a control potentiometer.

An alphanumeric liquid crystal module displays the frequency and range information. Four frequency outputs are provided:

- o) Direct output at ±1V peak-to-peak
- o) AC coupled output, fully variable between zero and 4V peak-to-peak
- o) Pulse output, 0V to 5V logic level
- o) 3·2768MHz fixed frequency, 0V to 5V logic level

The PIC is also used as a frequency counter, switch selectable to monitor the frequency generated by the MAX038, or from an external source in conjunction with a pre-conditioning waveform shaper and frequency divider. Two external signal inputs are provided: one for 0V to 5V logic level waveforms, the other for AC waveforms having a peak-to-peak swing of between about 2·5V to 5V. The prototype can monitor frequencies in excess of 40MHz.

STARTER PROJECT

An easy to build, inexpensive *Camera Shutter Timer*. It is not essential to use a complex digital timer to test camera shutters, and a very basic analog timer circuit is capable of providing accurate measurements in this application. The simple design featured here has four measuring ranges having full-scale values of 5ms, 50ms, 500ms, and 5 seconds. It can therefore be used to measure the full range of speeds covered by most cameras.

g-METER

This portable accelerometer will tell you the g-force you experience when you corner or brake hard in your car, when you ride in a lift or at the fairground. It is based on a tiny polysilicon micromachined sensor etched onto an integrated circuit. The earth's gravity is used as a reference standard.

As described, this is an experimental project designed as a simple introduction to the world of acceleration. The g-Meter output is in the form of a 10-segment bargraph type display, but for more accurate measurement or signal processing an output socket is provided. A fascinating project using just two ICs.

ATMOSPHERIC ELECTRICITY DETECTOR by KEITH GARWELL - Part 1

Investigate Nature's power-house with this intriguing experimental design.

It all started way back at the very beginning of the 1990s when the author saw an article in an astronomy magazine suggesting that it might be possible to detect the advent of a meteor by means of a change in the earth's electric field.

Whilst he never succeeded in doing this, confessing that it might be due to inadequacies in his equipment or design, detecting and measuring changes in the electrical state of the earth's atmosphere soon became an interesting hobby.

SCENE SETTING

The ionized layers of the atmosphere extend from about 40km to 200km (25 to 125 miles) above the earth. This ionization is caused by the "Solar Wind" passing the earth and leaves the upper atmosphere positively charged.

There is thus an electric field between the upper atmosphere and the earth. Using suitable instruments, this field can be detected as it results in a minuscule current through the atmosphere.

If a probe, consisting of a metal plate, is supported on an insulator one meter above ground the metal plate will acquire by conduction the same potential as exists at this level above ground. This would be true of any height, of course, but the meter is a nice standard unit.

A potential of around 100 volts is often present. In other words there is often a potential of 200 volts or more between your nose and toes! Of course nobody gets electrocuted because the resistance of the air is so high that only a very tiny current is present. This is why the actual values are so difficult to measure.

Modern operational amplifiers make it possible to measure the tiny currents but they object strongly to being subjected to such high voltages!

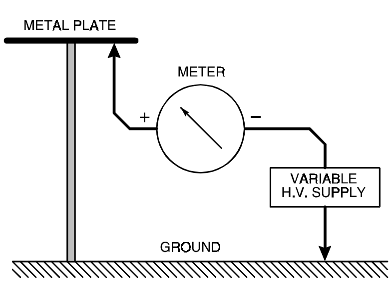


Fig.1. Basic principle of atmospheric electricity monitoring.

PRACTICAL MEASUREMENT

There is a way round this problem, as is illustrated in Fig 1. The metal plate is supported one meter above the ground and is connected to the positive terminal of a meter, which will indicate at least one picoamp. The negative side of the meter is connected to a variable high voltage supply, the other side of which is connected to ground.

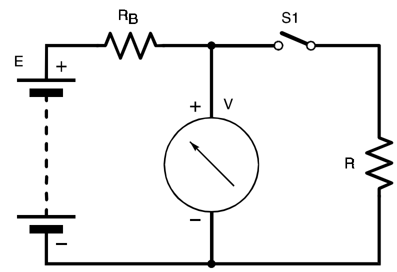


Fig.2. Equivalent circuit of Fig.1 in which atmospheric resistance can be measured.

If the power supply is now adjusted so that the current through the meter is zero, then the voltage from the power supply must be the same as the voltage on the plate.

We can also consider the plate as though it were a battery. Remembering school physics, a battery has potential and also internal resistance. Fig.2 suggests the arrangement whereby both these figures can be determined. The battery voltage is E volts and its internal resistance is R_B (the resistance of the atmosphere). Connected across the battery is a perfect voltmeter, i.e. it consumes no current. It is also possible to connect a resistor R across the battery by means of switch S1.

With the switch in the off position the voltmeter will show the voltage of the battery as E

volts. If the switch is now closed the voltage shown by the meter will fall due to the current flowing through R_B and R in series. Call this voltage V.

As the same current flows through both resistors their resistance will be proportional to the voltage across them. V is the voltage across R and the voltage across R_B is E – V. This gives:

$$R_B / R = (E - V) / V$$

Multiplying by R we get:

$$R_B = ((E - V) / V) \times R$$

and perhaps a more convenient form:

$$R_B = ((E / V) - 1) \times R$$

and finally:

$$R_B = (E \times R / V) - R$$

FIELD EFFECT

Although primarily intended for the observation of atmospheric electricity, the meter described here is very sensitive, quite easily constructed and doubtless adaptable to other fields of interest, including pollution.

Out of curiosity, the author set up the arrangement of Fig.1 in his lounge. The meter reading was zero until the TV was switched on, it then fluctuated rapidly and seemed to be related to the picture make-up!

Whilst Fig.1 allows the device to be used to determine the potential at a given height as well as a figure for the effective resistance of the air at that height, Fig.3 shows a method of obtaining a figure for the resistance of the air by direct measurement. It has been suggested that the resistance of the air and the amount of air pollution are inversely related.

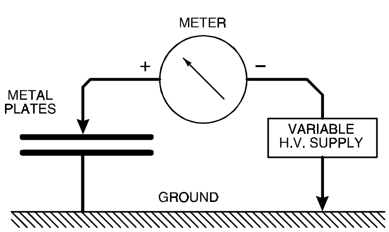


Fig.3. Principle for measuring the resistance of the air.

In Fig.3 the metal plate of Fig.1 is replaced by a pair of metal plates 140mm square and separated by 20mm. The separation can be achieved using two pieces of plastic tube. Make shallow slits 20mm apart in the side of the tubes with a saw and then push two opposite corners of the plates into the slits (see photo below).

The plates are supported one meter above ground and the lower plate is connected to ground. The high voltage supply can then be set to any voltage up to 300V and the meter will again indicate the voltage across its resistance and we end up with arithmetic similar to that used before. In this case the resistance (R_p) between the plates will be equal to:

((high voltage setting – meter reading) / meter reading) x meter resistance

TEST RESULTS

The author's results so far obtained by using the Fig.1 system are as follows:

Taken at a height of 0·5 meters from 1 Nov '99 to 19 Dec '99, from 41 readings the average voltage was 83·3V and the average resistance 10·1 tera ohms (one tera ohm = one million million ohms). The plate is one tenth of a square meter, so the figure for one square meter will be 1·01 tera ohms.

Taken at a height of one meter from 4 Jan '00 to 21 Feb '00, from 22 readings the average voltage was 69·2V and the average resistance 8·14 tera ohms, or 0·81 tera ohms per square meter.

All readings were taken under a blue sky with little breeze during the hours of daylight.

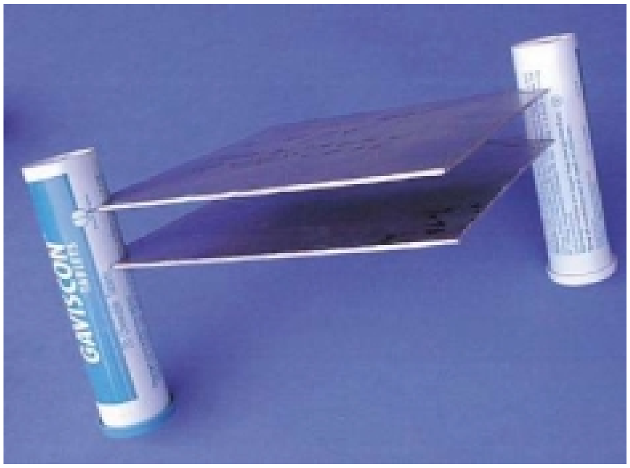
Using the two plates of Fig.3 a reading under calm but overcast conditions at a height of one meter gave a reading of 2·4V with 100V applied, giving an R_p value of 4·06 tera ohms. Corrected to a one meter cube gives 4 tera ohms. The correction on the two plates is 0·98.

It is not clear what the relationship is between the two possible resistance values, if indeed there is one! There are lots of other questions to be answered, for example the value given for E at a height of 0·5m was greater than the one obtained for 1m.

This is contrary to expectations, it would seem reasonable to expect a more or less linear increase in E with height, and ideally this could be solved by simultaneous measurement at several heights. The difficulty here is that the values change quickly so the author is waiting for a nice calm day when conditions are stable before drawing further conclusions.

EXPERIMENTAL ASSEMBLY

The equipment needed to perform such measurements is fairly simple to construct, there being only one or two spots where special arrangements are required, mostly concerned with maintaining the required insulation resistance. It can be split into six parts:



Practical plate construction for use with the test schematic in Fig.3.

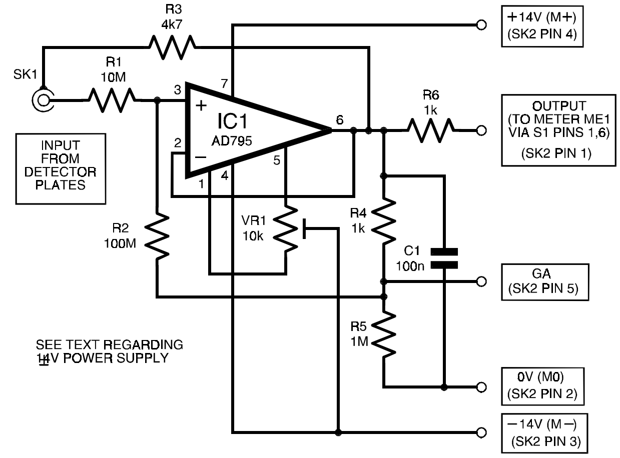


Fig.4. Circuit diagram for the meter interface buffer.

- o) High resistance meter interface
- o) Variable high voltage supply
- o) System metering
- o) System interconnections
- o) Probes (plates)
- o) Construction

Note that the 300V variable voltage supply also incorporates an isolated ±14V supply for the meter. This is necessary because, as Fig.1 shows, there can be a high voltage present between the meter and ground. This high voltage supply is inherently safe because it is designed with a very limited current capability.

METER CIRCUIT

The schematic in Fig.4 shows the basic circuit diagram for the meter interface buffer. (The meters will be discussed next month.) When the input is connected via socket SK1 to a suitable antenna or probe (e.g. the metal plate mentioned with regard to Fig.1 and Fig.3), this circuit allows atmospheric electricity to be monitored via a suitable meter connected to its output. It is quite simple to construct although there are one or two peculiarities.

First note that the use of an AD795 for opamp IC1 is not essential but if an alternative is sought its input bias current must be very small because it is passing through a 100MΩ resistor (R2). The AD795 bias current is less than 1pA and the offset voltage less than 250uV. The input resistance of this design is 100,000,000,000 ohms, perhaps better described as 10^{11} ohms or 100 gigohms (GΩ).

The circuit is basically a voltage follower hiding behind one or two minor modifications. It requires a power supply of between ±12V and ±15V.

Resistor R1, in series with the input to the opamp (pin 3), is a protection resistor. This meter interface is intended to be mixed up with static and various other unpleasant things, at least unpleasant as far as semiconductors are concerned. As a consequence, R1 is intended to reduce the possibility of damage to IC1. Although R1 is 10MΩ, this value is of no consequence to the normal operation because of the effective input resistance of IC1.

Next, one would expect the input bias resistor (R2) to be connected to the 0V line. Instead, connecting it to the junction of resistors R4 and R5 effectively multiplies its value by 1000. This is how the massive input resistance is achieved. R2 is already large, 100MΩ, multiplying it by 1000 gives the required figure. This arrangement is known as bootstrapping, although the term is also applied to other similar techniques. How this works is most easily seen by going through an example:

Suppose the input at pin 3 is 1V, the output at pin 6 will also be 1V. The ratio of R4 to R5 is one to a thousand so that the voltage across R4 will be 0·99mV. Let's call it 1mV as a close approximation. Under this the voltage across R2 will be 1mV and the current through it equals 1mV / 100MΩ (I = V / R), that is $10^{-3} / 10^{-8}$ or 10^{-11} amps. However, the voltage at pin 3 is 1V and the current taken is 10^{-11} amps. The effective resistance must therefore be $1 / 10^{-11}$, which is 10^{11} ohms.

The next point to be made is about resistor R3. This provides what is known as the guard connection. As it is necessary to use an input cable that is

The author's prototype single-plate atmospheric detection platform.

screened to connect the meter interface, the screen is connected to R3. There is thus no voltage difference between screen and the conductor, so that leakage is minimized.

Lastly, capacitor C1 stabilizes the opamp to prevent the possibility of high frequency oscillation and also serves to prevent interference gaining access via either the input or output connection.

Note that the connection labeled GA is not used.

DUAL VOLTAGE POWER SUPPLY

Harking back to Fig.1 for a moment, the meter will be operating at some considerable potential above ground because, whilst the open circuit voltage on the plate E is being measured, both the input and the 0V line of Fig.4 will be at the same potential. This means that the dual power supply for the meter interface must be isolated from ground and this supply is generated in a common unit along with the high voltage supply.

In fact there are limits on the power supply. A lower limit of ±12.5V is set by the opamp type in the meter interface circuit (IC1 in Fig.4) which must provide an output from –10V to +10V. Usually there is a requirement for an allowance (known as headroom) of about 2·5V between the supply and the maximum output voltage.

An upper limit is set by the opamp manufacturer and is very often ±15V with an absolute maximum of ±18V.

Consequently, the value chosen for the prototype is ±14V, which makes allowance for both requirements. This supply is generated using a separate circuit to be described in a moment.

A continuously variable high voltage supply from 0V to at least 300V of either polarity must also be generated. This supply must be inherently safe, or at least the user must be! This is achieved by arranging that the high voltage supply has a high internal resistance so that the output current is very limited. This supply must also be isolated from ground so that it can be switched to either polarity.

There is also the question of what primary power source is to be used and a 12V battery was chosen. This makes the equipment portable and also safe from mains failure. As in the author's set-up the battery is simultaneously charged from the mains, it was preferable that a voltage of between 11·5V and 13·8V should be allowed for the primary source. This is all achieved as shown in Fig.5.

POWER SUPPLY GENERATOR

In this circuit IC2 is configured as an oscillator whose output is coupled to two transformer and rectifier circuits. The first, based around transformer T1, generates ±14V. The second, based around T2, is a variable generator which can be set for any voltage between 0V and 300V, approximately.

Op.amp IC2 is in fact an audio power amplifier. However, it will also operate as a power oscillator and this is how it is used here. Capacitor C2 determines the frequency, in this case about 50kHz. Diode D1, resistor R8 and capacitor C3 are bootstrap components for pin 7 so that the IC can achieve a voltage output close to the supply rails.

Output pin 5 drives the primaries of the two transformers T1 and T2, via capacitors C4 and C5 respectively. The output of T1 is rectified by diodes D2 and D3, smoothed by capacitors C6 and C7, and regulated at ±14V by the Zener diodes D7 and D8.

The output of T2 is applied to a voltage doubling circuit, comprising D4, D5, C8 and C9. The drive to its primary is controlled by TR1 and D6, the affect of which depends on the base current produced by the DC voltage applied to R11 from the high voltage adjustment control input.

Note that capacitors C8 and C9 must be rated at 250 volts working and therefore all the

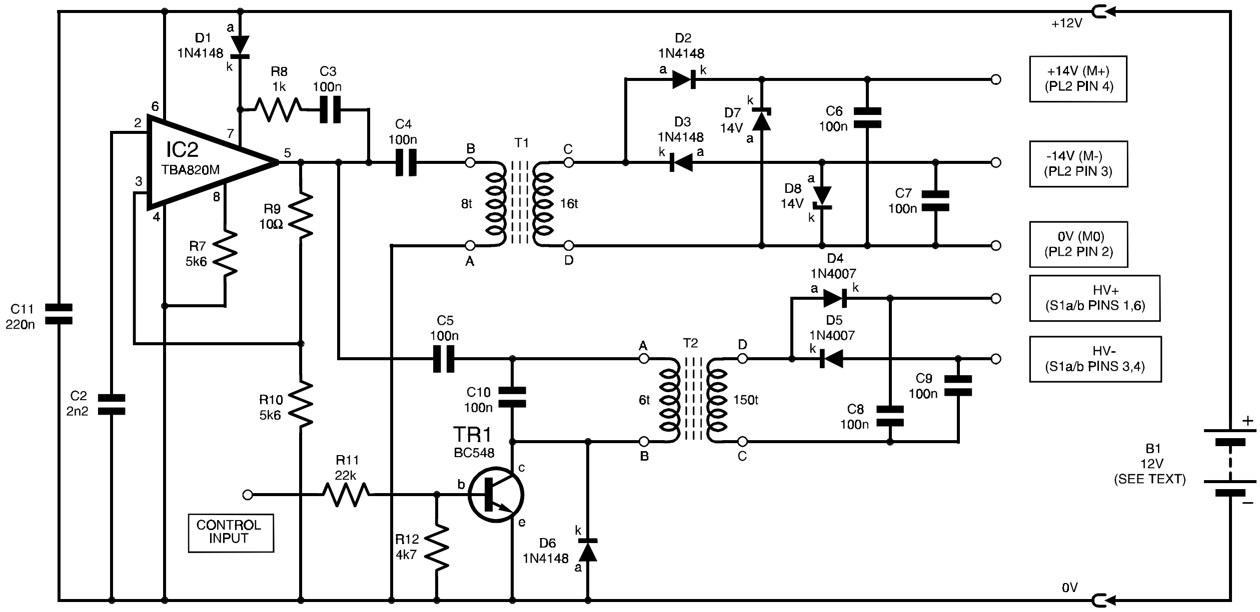


Fig.5. Dual voltage power supply generation circuit diagram plus variable 300V supply.

100nF capacitors have been specified at the same rating.

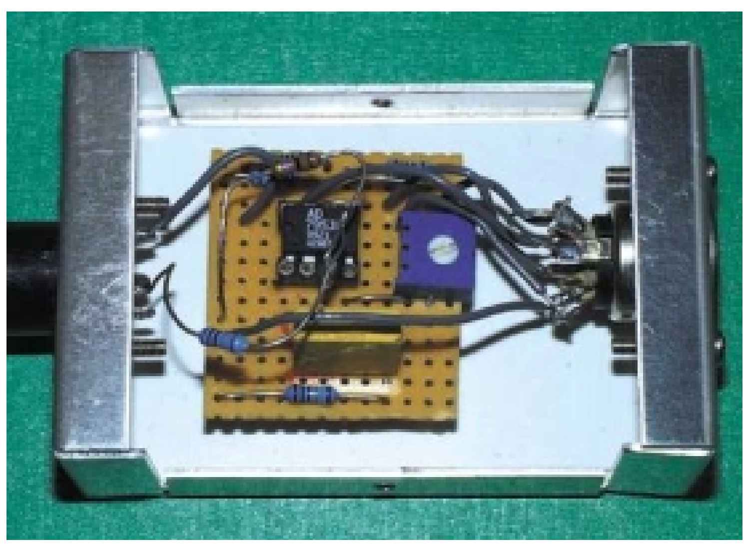
METER INTERFACE CONSTRUCTION

The meter interface circuit can be built using stripboard and a layout is suggested in Fig.6. It is prudent to use a socket for IC1 so that it can easily be replaced if it does have a mishap. Always ensure that IC1 is correctly orientated.

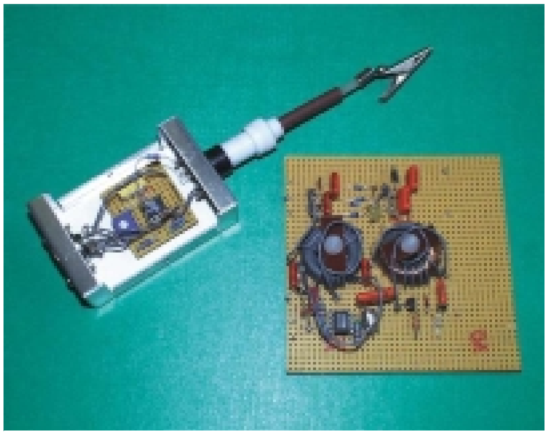
The most important part of the construction to be noted is that pin 3 of IC1 must be bent out sideways so that when the IC is fitted pin 3 is well away from the board. The two resistors R1 and R2 are soldered directly to pin 3 and supported on their wires and should not touch anything!

During the setting up operation the input must be entirely screened. This is most easily done by mutilating a standard cable mounting coaxial plug. To do this unscrew the cap and remove the central conductor and the cable clamp. Then bung up the cap with a scrap of aluminum foil crushed into a ball. This should be a firm fit in the cap. Replace the cap on the body of the plug and the job is done.

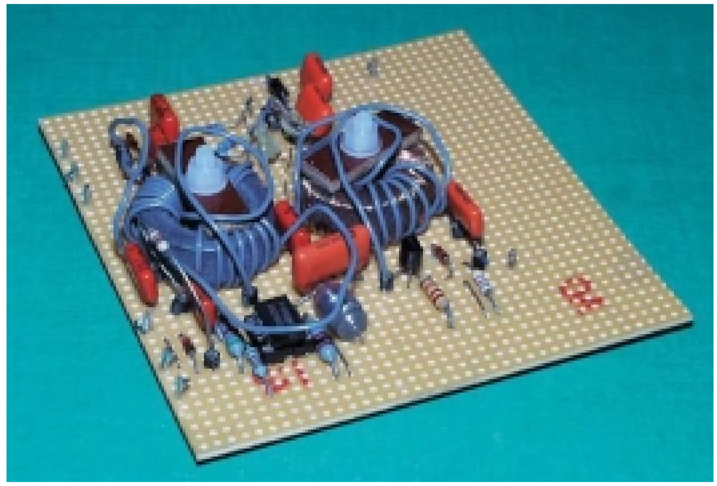
Connector SK2 is a 7-pin DIN socket and SK1 is a TV aerial socket. The latter is special in that both center connector and the screen connector must be insulated from the aluminum case. There are some connectors which are in a plastic molding and one of these will be fine. If this type is not available then the more normal socket with the metal outer can be used but it will have to be insulated from the case by mounting it on a piece of insulating board.



The meter interface board mounted in its case. A piece of card is placed between the board and bottom of case to prevent any "short circuits".



Meter interface unit complete with crocodile clipped connection link, plus the constructed power supply board.



Close up details of the constructed power supply board.

An aluminum case needs to be used, measuring about 76mm x 50mm x 25mm. The DIN socket should be fitted at one end and the TV coaxial socket at the other.

POWER SUPPLY CONSTRUCION

The secondary winding on the high voltage transformer T2 is 150 turns of 36 gauge (0·2mm) enameled wire. For those who haven't played this game before, use a shuttle. This can be made from a piece of card or plastic that will pass through the center of the toroid and which has a slot at either end so that the wire can be wrapped round the shuttle lengthwise.

It is as well to first put 10 turns on the toroid the hard way, take it off and measure it so that the required length for 150 turns can be worked out. Allow plenty for the ends. The wire is much cheaper than patience!

The primary for transformer T2 has only six turns. For T1, the primary has eight turns and the secondary 16 turns. As the other windings have only a few

COMPONENTS

Resistors
R1 10M
R2 100M high ohmic cermet film
R3 4k7
R4, R6 1k (2 off)
R5 1M
R7 5k6 1% metal film
R8 1k 1% metal film
R9 10k 1% metal film
R10 5k6 1% metal film
R11 22k 1% metal film
R12 4k7 1% metal film
R13 100k
R14 22k
R15 3M
All 0.25W 5% carbon film or better unless
otherwise indicated

Potentiometers
VR1 10k miniature preset, square
VR2 50k miniature preset, round
VR3 10k carbon rotary

Capacitors
C1 100n polyester, 12.5mm spacing
C2 2n2 polystyrene
C3 to C10 100n polyester, 250V (8 off)
C11 220n polyester, 250V

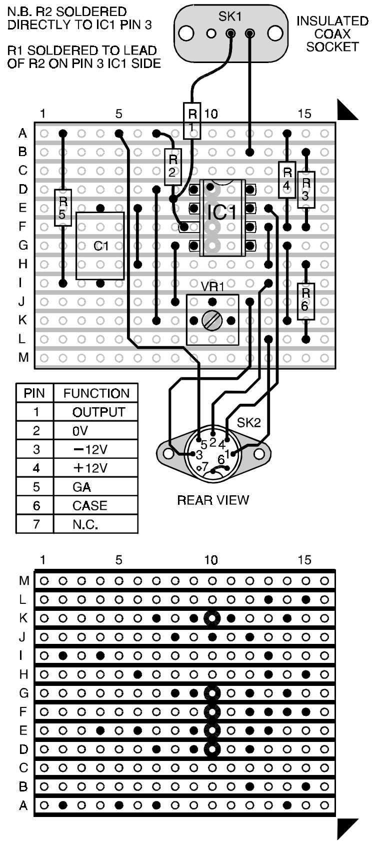
Semiconductors
D1 to D3, D6 1N4148 signal diode (4 off)
D4, D5 1N4007 rectifier diode (2 off)
D7, D8 14V 400mW Zener diode (2 off)
TR1 BC548 *npn* transistor
IC1 AD795 opamp
IC2 TBA820M power opamp

See also the SHOP TALK Page!

Miscellaneous
B1 12V battery (see text)
B2 AA cell (2 off)
SK1 coax socket, insulating (chassis mounting) (see text)
SK2 7-pin DIN socket (chassis mounting)
S1 d.p.d.t. miniature toggle switch
S2 s.p.s.t. miniature toggle switch
S3 d.p.d.t. toggle switch, 240V AC rated
S4 s.p.d.t. toggle switch, 240V AC rated
PL1 coax plug (cable mounting)
PL2 7-pin DIN plug (cable mounting)
ME1, ME2 panel meter, 0.1mA full scale deflection (2 off)
T1, T2 ferrite toroid B64290K618X830 (25mm diameter) (2 off)

Stripboard, 0.1-inch, 39 strips x 39 holes; stripboard, 0.1-inch, 12 strips x 13 holes; metal case 75mm x 50mm x 25mm; metal case to suit power supply
control unit (see text); knob for VR3; 8-pin DIL socket; crocodile clip; 36 gauge (0.2mm) enameled wire (see text); nylon nut and bolt to suit (see text)
(2 off each); aluminum plate 316mm x 316mm x 2mm (or thicker); support hardware (see text); 6-way cable

Approx. Cost Guidance Only ***(Excluding batteries, meters, cases, and hardware)*** **$30**



PIN	FUNCTION
1	OUTPUT
2	0V
3	−12V
4	+12V
5	GA
6	CASE
7	N.C.

Fig.6. Meter interface stripboard component layout, details of breaks required in underside copper tracks and wiring to off-board components.

turns, so the wire can be threaded through. Plastic covered connection wire will do, e.g. 1/0·6.

Assembly details for the power supply board are shown in Fig.7. There is nothing special about the layout so it can be varied to suit different component sizes. Be careful with the cuts in the tracks since these must be done on the reverse side. It is easiest to poke something through from the front to help mark a cut position.

The two transformers should be fastened to the board, ideally using a nylon nut and bolt, passing the bolt through a piece of plastic, through the center of the toroid and through a hole in the matrix board. Tighten the nuts just sufficiently to hold the toroids in place.

NEXT MONTH

In the final part next month we conclude the construction and describe the metering and monitoring probes.

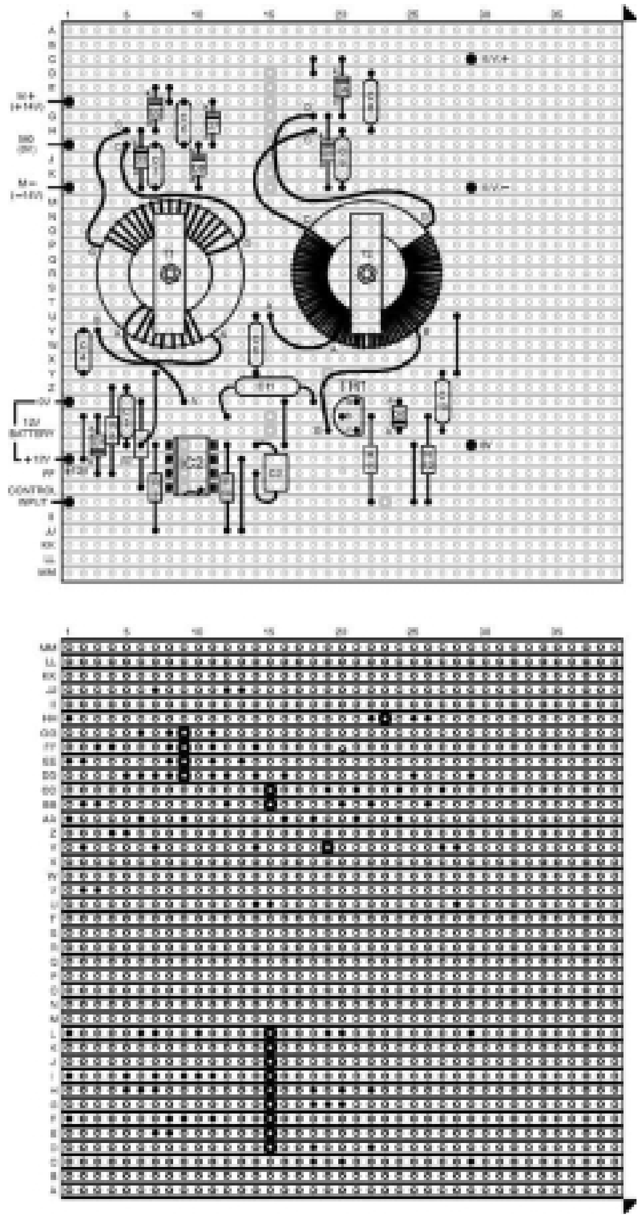


Fig.7. Power Supply stripboard, topside component layout and underside copper track break details. Note that the two toroid transformers are bolted to the board using nylon nuts and bolts and two strips of plastic

Ingenuity Unlimited

ROLL-UP, ROLL-UP!

Ingenuity is our regular round-up of readers' own circuits. We pay between $16 and $80 for all material published, depending on length and technical merit. We're looking for novel applications and circuit tips, not simply mechanical or electrical ideas. Ideas must be the reader's own work **and must not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should preferably be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.**

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Win a Pico PC-Based Oscilloscope

- **50MSPS Dual Channel Storage Oscilloscope**
- **25MHz Spectrum Analyzer**
- **Multimeter**
- **Frequency Meter**
- **Signal Generator**

If you have a novel circuit idea which would be of use to other readers, then a Pico Technology PC based oscilloscope could be yours.

Every six months, Pico Technology will be awarding an ADC200-50 digital storage oscilloscope for the best IU submission. In addition, two single channel ADC-40s will be presented to the runners up.

Voltage Booster – High Voltage from a 5V Supply

Digital circuits operating from 5V regulated supplies are common but occasionally a higher voltage is required, perhaps for a bio-medical circuit, or for liquid level measurement or for monitoring high resistance contacts. For such circuits a means of generating a high voltage from the 5V supply can be a solution. Diode/capacitor multipliers can offer advantages over switched-mode circuits, since they do not use inductors, are easier to design and trouble-shoot and often generate less radiated interference.

The principle of the voltage multiplier is fairly well known. A capacitor is used with a square wave drive signal to "pump" current through a pair of diodes, roughly doubling the supply voltage. A series of such stages can be cascaded to raise the voltage in multiples of the supply, but it is possible to improve efficiency

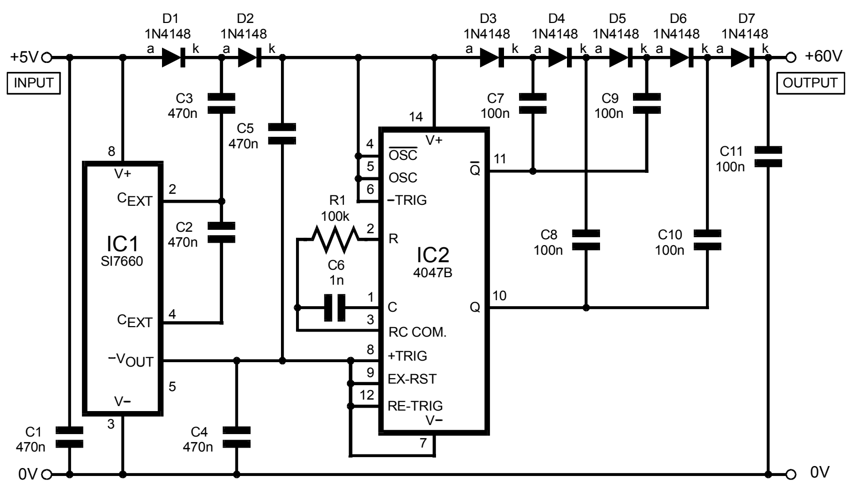


Fig.1. Circuit diagram for a Voltage booster. Will boost a 5V input up to about 60V, off load.

and reduce the number of stages by using two driving signals with opposite phases. However, each diode incurs a drop of about 0·6V so with two diodes per stage, and with an initial supply of just 5V this becomes significant, leading to poor efficiency and an impractical number of stages.

These problems are overcome in the Voltage Booster circuit design of Fig.1 by increasing the voltage before multiplication with IC1, an SI7660 "negative rail generator" (not the ICL7660 – ARW). The additional negative supply is generated

very efficiently since switching is performed not by diodes but by CMOS switches in the IC, which cause almost no voltage loss at low currents.

Pin 2 of this IC also drives a diode multiplier which, even though it does suffer from diode voltage drops, still generates about +8·8V. With a minimum of components this device generates a pair of supply rails with an overall potential of more than 13·5V.

This voltage is supplied to IC2, a 4047B used as an oscillator whose frequency is set to about 400Hz by resistor R1 and capacitor C6. The oscillator employs an internal divide-by-two stage so that the outputs at pin 10 and pin 11 are complementary 200Hz square waves with perfect 1:1 duty cycles, ideal for multiplier driving.

With just the five diodes D3 to D7 shown, the circuit generates 60 volts with no output load. The output may be treated as having a fairly linear source resistance of about 200k since a drop of about 10V results for each 50uA of current drawn. In other words it will sustain 50V across a 1M resistor, or about 40V across one of 390k.

At no load the quiescent current was measured at just 650uA rising to about 1·9mA at 100uA load. The capacitors used were all resin-dipped ceramic types, though other non-electrolytic types with suitable voltage ratings could be used. The diodes are inexpensive 1N4148 signal types.

Increased output power could be obtained by using a higher frequency for IC2 and larger capacitors for C2 and C3, though this would increase the standby current. More (or less) stages in the multiplier chain could be used to obtain different output voltages if needed.

Finally, the value of capacitor C11 could be increased to allow the build-up of a larger charge, but this would obviously cause a time lag at switch-on or discharge. The circuit reaches full output voltage in well under a second.

Andy Flind
Taunton, Somerset, UK

Air-Flow Detector – A Cool One

In some electronic circuits there may be a need to provide air-cooling of components that might otherwise overheat. Where convection cooling is insufficient, fan assistance is required. Should the fan fail, or if the air vents become blocked, damage to the equipment may ensue. In the case of critical applications involving expensive equipment, it would be desirable to have some means of monitoring the air-flow and either signalling a fault or shutting down the system if the air supply should fail.

The circuit diagram of an Air-Flow Detector is shown in Fig.2. The pivotal component is the special thermistor R1, which is made of a material that has a critical temperature characteristic of 140°C. At this point, the material exhibits a high impedance.

If the thermistor is allowed to self-heat, it hovers around this critical temperature, with some of the material in a high impedance state, with the remainder just below, being cooler through surface conduction. This provides a conduction path by which the thermistor maintains its temperature. This component is placed in the airflow.

Initially at switch on, thermistor R1 is cold and will draw about 340mA which will heat it up rapidly. If its temperature is allowed to rise, it will eventually come to its critical temperature point where its resistance increases, thereby restricting the

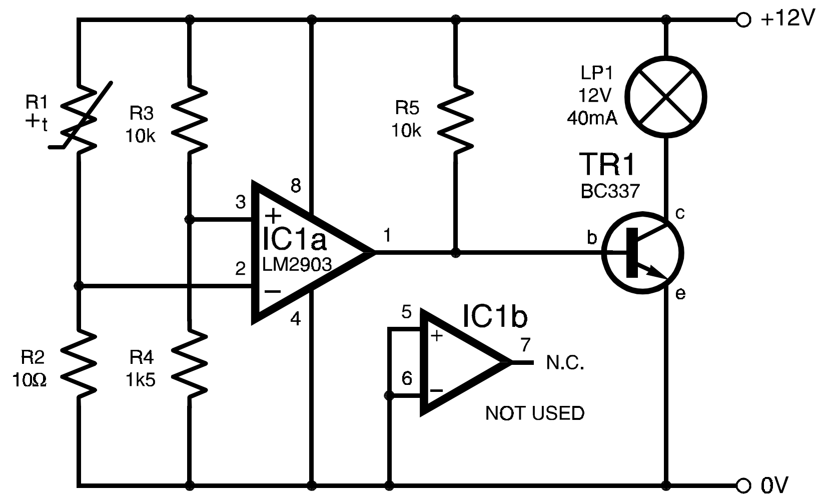


Fig.2. Circuit diagram for an Air-Flow Detector. The thermistor R1 is a positive temperature coefficient type and has a resistance of 25Ω @ 25°C. One is listed by Farnell as code 478-090.

current, and reducing its dissipation. In still air, it will draw about 100mA. However, if air-cooling is present, it will be able to maintain a higher dissipation, and draw more current.

Resistor R2 develops a voltage in proportion to this current and resistors R3 and R4 form a potential divider, applying 1·56V to pin 3 of comparator IC1a. In normal operation, with proper air cooling, pin 2 of IC1a remains above pin 3, and the output of the comparator is held low.

Should the air-cooling fail, the voltage at pin 2 will drop, and the output will go open circuit. The current supplied by resistor R5, which had previously sunk into pin 1 of IC1a, now forward biases transistor TR1 and switches it on, which illuminates the warning lamp LP1.

The circuit may be adapted for other operating voltages, obviously ensuring that the power supply can cope with the relatively high current demands. However, it was found that the circuit would not operate effectively at 5V, as there is insufficient initial dissipation in thermistor R1 to cause it to reach its critical temperature.

The indicator lamp may be replaced by a LED with series resistor, or supplemented by an audible warning device. Alternatively, the output of IC1a may be pulled up via a resistor to a +5V rail, and the comparator's output used as a logic signal.

Dave Andrews
Ryde, Isle of Wight

Clock Detector – Time Out

The Clock Detector circuit diagram of Fig.3 could be used in applications that need an indication that a digital clock or digital data is present. The digital signal to be monitored is fed to the circuit and the output of the circuit gives a TTL level indication such that when a clock signal is present, the output equals "1" and vice-versa.

The input signal is first AC coupled to IC1 non-inverting input, via capacitor C1, and can be any type of logic signal – TTL, CMOS, ECL, etc. The diodes D1 and D2 form a peak detector by clipping the AC signal between –0·7V and the positive amplitude of the signal. The alternations of the clipped signal are then filtered by capacitor C2 and resistor R1. The time constant R1.C2 should not be too small when compared to the time period of the clock or data signal: a factor of 10 is a good choice.

When there is a clock signal present, or data with enough 0-1 transitions, then the clipped AC.-coupled signal after diodes D1 and D2 will have a DC voltage (filtered out by C2 and R1) which is larger then zero. This

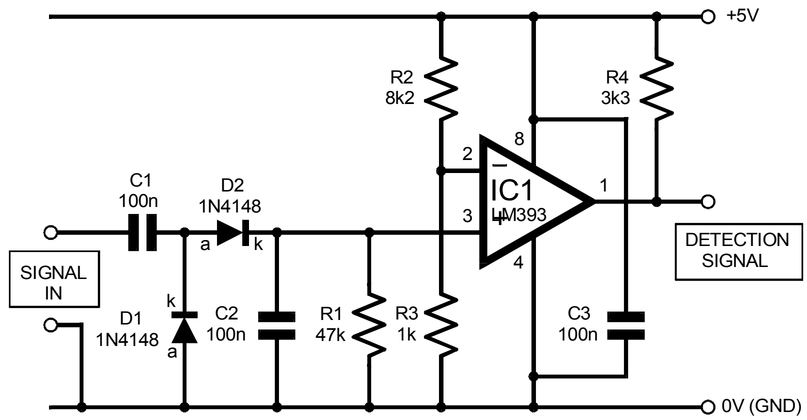


Fig.3. Circuit diagram for a Clock Detector.

DC level is then compared by IC1 against the voltage set by the divider resistors R2 and R3. If the DC level is higher than (1k/ 9k2) x 5V = 0·54V, then the comparator goes to a logic high level, which indicates that there is a signal present.

The circuit was used for clock frequencies up to 100MHz, but the circuit can be adapted for even higher clock speeds. For higher speeds, the diodes D1 and D2 should be replaced by Schottky types, as they are faster for the clipping action. The coupling capacitor C2 should be chosen in such a way that it doesn't attenuate the signal too much.

The value of resistor R1 is quite high, because it directly determines the load on the signal to be measured. Resistor R4 is needed because the comparator has an open collector output.

An LM393 dual package was used for IC1. The second comparator can be used e.g. as an oscillator, as these comparators have a hysteresis feature.

M. Van De Weghe
Zottegem, Belgium

PICO PRIZE WINNERS

It's time once again to award three lucky Ingenuity Unlimited contributors with prizes of superb PC-based oscilloscopes, generously donated to *Everyday Practical Electronics* by PICO Technology. You can learn all about PICO's versatile and cost-effective range of test equipment by visiting their web site (www.picotech.com). Our thanks go to PICO for encouraging our readers' spirit of ingenuity once again.

All entries were judged on the criteria of originality, "lateral thinking" or novelty, technical merit, re-sourcefulness, appropriateness and overall completeness. Presentation was used as a tie-breaker. The final choices were selected by *EPE* Editor Mike Kenward and *Ingenuity Unlimited* host Alan Winstanley from the wide variety of entries in the December 1999 – May 2000 issues.

WINNER – receives a superb PICO ADC200-50 Digital Storage Oscilloscope, worth over 450 UK pounds!

LEE MATTHEWS – Class-D 30W Audio Amplifier (Dec. 99)

This idea was fully presented and used a number of novel circuit techniques to produce a high-efficiency audio amplifier.

RUNNERS-UP – both are lucky winners of PICO ADC-40 single-channel PC-based oscilloscopes.

P. McLEOD – Mini Disc Optical Interface (Feb. 2000)

A perfect example of lateral thinking, adapting a fibre-optic encoder with a CD-ROM drive to produce an optical interface for digital recording purposes.

JOHN A. HAAS – Experimenter's Power Supply (May 2000)

Although using a traditional regulator, the circuit had been carefully optimized using external voltage references to produce a handy 0.25V power supply for benchtop and hobbyist use.

Constructional Project

AUTOMATIC NIGHTLIGHT

by ROBERT PENFOLD

This latest, low-cost starter project is sure to be a turn-on. Just a gentle tap or clap will trigger it into life.

This simple nightlight starter project is switched on simply by tapping on the case, or gently clapping one's hands close to the unit. The low power bulb then switches on for approximately five minutes, but it can be switched off at any time by operating a Reset button on the top of the case.

The unit was primarily designed with children in mind, but it could obviously be a useful gadget for adults as well, particularly disabled people. It is battery powered and is therefore safe for use by small children. The simple circuit and lack of mains power also makes this project suitable for construction by complete beginners.

SYSTEM OPERATION

The block diagram of Fig.1 helps to explain how the Automatic Nightlight functions. It is based on a monostable, which is simply a circuit that provides an output pulse of a certain duration each time it is triggered. In this case we require the light bulb to be switched on for about five minutes, and the timing components in the monostable are therefore chosen for an output pulse of this duration.

The monostable cannot provide sufficient current to power the bulb, which is therefore controlled by way of a single transistor output stage. Also, an input of the monostable permits the output pulse to be terminated prematurely and the Reset switch controls this input.

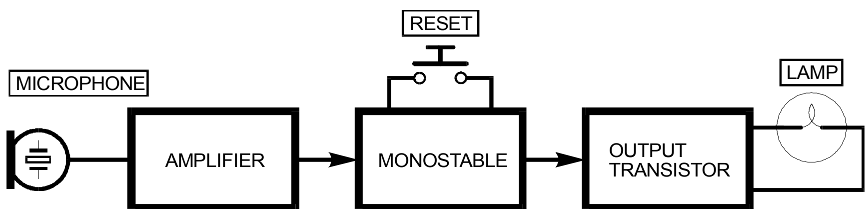
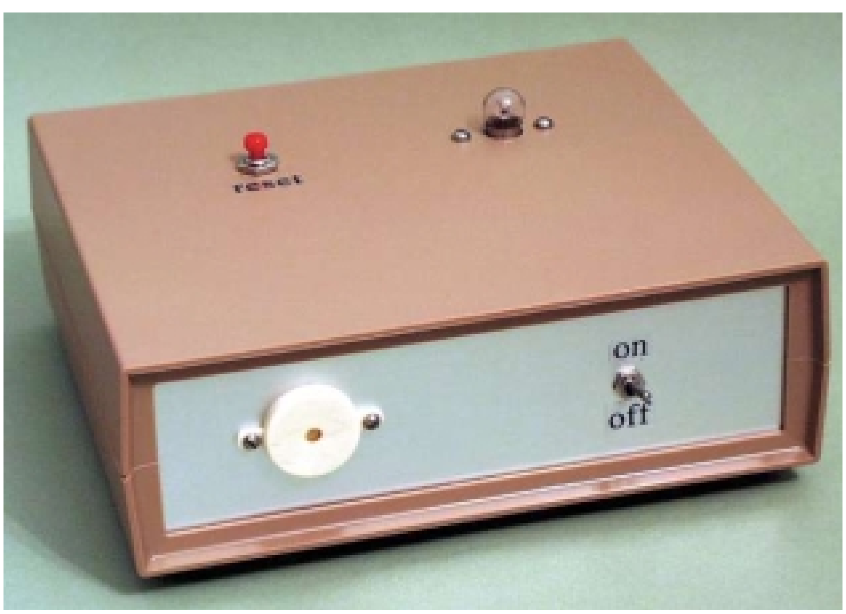


Fig.1. Block diagram for the Automatic Nightlight.

A piezoelectric microphone is used to provide the trigger signal for the monostable, but the output signal from the micro phone is too low to provide reliable triggering. A single stage amplifier is therefore used to boost the signal from the microphone to a level that gives better results.

The sensitivity of the circuit is still quite low, but high sensitivity is not an advantage in this application. It would simply result in frequent spurious triggering of the unit, and operating the Reset switch would produce vibrations that would immediately re-trigger the unit.



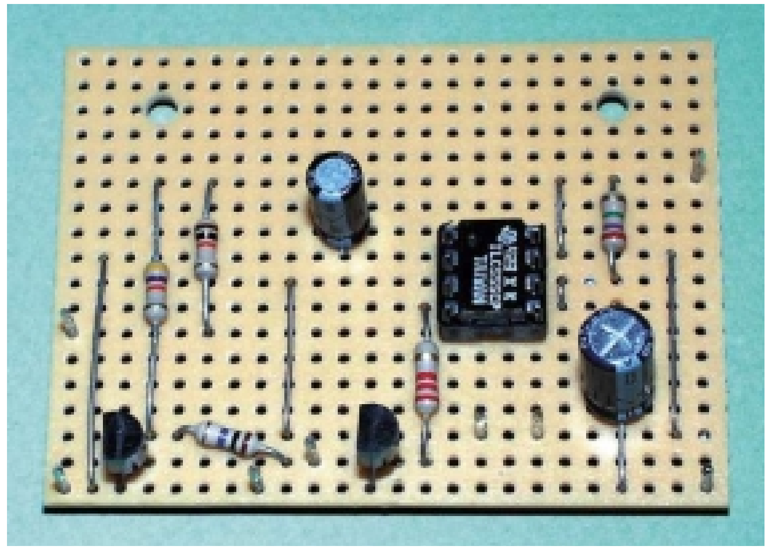
CIRCUIT OPERATION

The full circuit diagram for the Automatic Nightlight project appears in Fig.2. It is based on a low power version of the 555 timer (IC1) used in the standard monostable mode. It is important to use a *low power* 555 in this circuit, because it will be left switched on, but in the standby mode, for long periods of time.

The standard 555 has a current consumption of only a few milliamps, but over a period of several nights this would significantly drain the batteries. A low power 555 consumes only a fraction of a milliamp, and should not greatly drain the batteries, even after a few months of use.

ON TIME

The timing components in the monostable are resistor R3 and capacitor C2. Under standby conditions an internal transistor of IC1 places a virtual short circuit across C2 that prevents it from charging via R3. This short circuit is removed when IC1 is triggered, and C2 then charges via R3 until the charge potential equals approximately two thirds of the supply potential. The internal transistor then switches on again, and almost instantly discharges capacitor C2.



Completed circuit board showing the component layout and the use of an IC socket for the low power 555 timer IC.

Under standby conditions the output at pin 3 of IC1 is low, but it goes high while capacitor C2 is charging. The output pulse duration is equal to approximately 1·1 *CR* seconds, with the capacitance value in microfarads and the resistance in megohms.

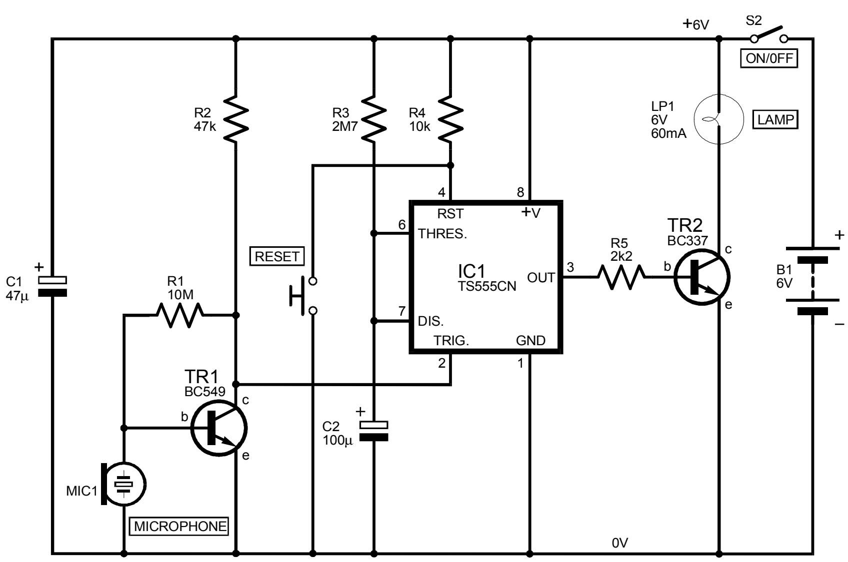


Fig.2. Complete circuit diagram for the Automatic nightlight.

With the specified values this works out at 297 seconds, or just under five minutes in other words. In practice the pulse duration is likely to be somewhat longer than this due to slight leakage in C2, and it is not possible to set highly accurate output pulse times with a simple circuit of this type.

In the present application highly accurate results are not required, and any slight lack of consistency in the output times is also of little importance. Different output times can be produced by changing the value of resistor R3 and (or) capacitor C2, but times of more than about 20 minutes become increasingly unreliable due to the high values involved. However, longer times are not really needed in this application, and for most purposes the specified values will suffice.

LIGHTING UP TIME

Although light bulb LP1 is a low current (60mA) type, it still requires more current than IC1 can supply. Consequently, it is driven via common emitter switching transistor TR2. When the output of IC1 goes high TR2 is biased into conduction, and LP1 is

COMPONENTS

Resistors
R1 10M
R2 47k
R3 2M7
R4 10k
R5 2k2
All 0.25W 5% carbon film

Capacitors
C1 47u radial electrolytic, 16V
C2 100u radial electrolytic, 10V

Semiconductors
TR1 BC549 *npn* general-purpose transistor
TR2 BC337 *npn* medium-power transistor
IC1 TS555CN low power timer

Miscellaneous
MIC1 cased piezoelectric sounder
LP1 6V 60mA bulb, with holder
S1 push-button switch, push-to-make, release-to-break
S2 s.p.s.t. miniature toggle switch
B1 6V battery pack (4 x AA cells in holder)

Medium size plastic or metal box, style and size to choice; 0.1 inch matrix stripboard, 24 holes by 18 copper strips; 8-pin DIL socket; PP3 type battery connector; multistrand connecting wire; solder pins, solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only (Excluding Batts & Case) **$10**

supplied with virtually the full 6V supply. Resistor R5 prevents an excessive base current from flowing into TR2.

The circuit can handle higher output currents incidentally, but do not use a bulb having a rating of more than about 250mA. Of course, using a bulb having a current rating of more than 60mA will significantly shorten the battery life.

Resistor R4 takes the reset input of IC1 (pin 4) high so that the monostable functions normally. Pressing switch S1 pulls pin 4 low and causes the output pulse to be terminated immediately. Of course, pressing S1 has no effect if LP1 is not switched on.

INPUT TRIGGER

The trigger input at pin 2 of IC1 is driven from the output of a simple common emitter amplifier based on transistor TR1. To trigger the monostable this input must be taken below one third of the supply voltage. The high value of bias resistor R1 ensures that under quiescent conditions the output voltage at the collector (c) of TR1 is half the supply potential or more.

When the microphone MIC1 picks up a sound the collector voltage of TR1 moves either side of its normal level, and if the signal is strong enough the voltage will briefly go below one third of the supply potential and trigger IC1. Microphone MIC1 is actually a piezoelectric sounder and not a proper microphone. In this application audio quality is not a consideration, and a piezo sounder used in reverse as a crude crystal microphone gives good results at low cost.

It is important that the current consumption of the amplifier is very low so that good battery life is obtained. The current drawn by transistor TR1 is typically about 60uA, and the quiescent current consumption of the circuit as a whole is approximately 250uA.

CONSTRUCTION

This battery-powered Automatic Nightlight, the latest in our special series of low-cost starter projects, is built up on a small piece of stripboard. The topside component layout, underside details and interwiring to off-board components is shown in Fig.3. Containing just 24 holes by 18 strips the board is not a standard size and a larger board must be trimmed down to this size using a hacksaw or a junior hacksaw.

The two mounting holes are 3mm diameter and will accept either 6BA or metric M2.5 mounting bolts. Most plastic stand-offs do not work well with stripboard and it is better to use mounting bolts plus spacers to keep the underside of the board clear of the case.

The seven breaks in the copper strips can be made using a special tool, but a handheld twist drill bit of about 5mm diameter will do the job just as well. The circuit board is now ready for the components and link-wires to be added.

Most low power versions of the 555 timer are not static-sensitive, but it is still advisable to mount this component on the board via a holder. Be careful to fit both capacitors with the correct polarity.

Capacitor C2 must be a good quality component if the unit is to function properly. Using a low grade capacitor will either give greatly extended output pulses from the monostable, or once triggered the lamp will simply stay switched on indefinitely. A tantalum capacitor is ideal, but a good quality electrolytic component should give good results.

The five link-wires are made from 22s.w.g. or 24s.w.g. (about 0·6mm diameter) tinned copper wire. Fit single-sided solder pins to the board at the points where connections to the switches, the microphone, etc. will eventually be made.

CASE

A medium size plastic or metal box will comfortably

accommodate all the components. It is best to mount Reset switch S1 on the top panel where it will be easy to operate.

The microphone can be mounted behind the front panel, but a large round cutout will then be needed for the body of the component. It is easier to mount it on the front surface of the panel, and only three small holes are then required.

Two of these are for the metric M2 or 8BA mounting bolts, which are not normally supplied with the sounder incidentally. The third hole allows the two flying leads to pass through to the interior of the case. The sounder can be used as a template when marking the positions of the mounting holes.

Piezo sounders usually have one black lead and one red one, which is presumably to indicate their phasing. They are not polarized components though, and can be connected either way round in this case.

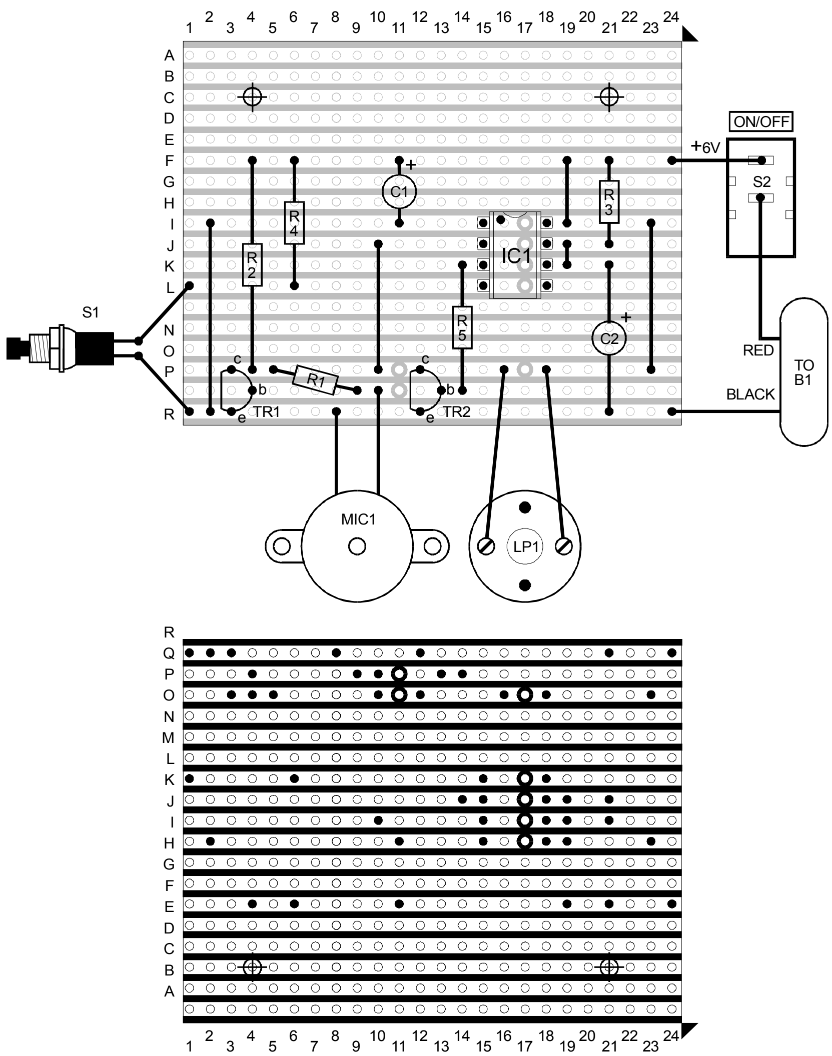


Fig.3. Stripboard topside component layout, details of breaks in the underside copper strips and interwiring to off-board components.

LIGHT WORK

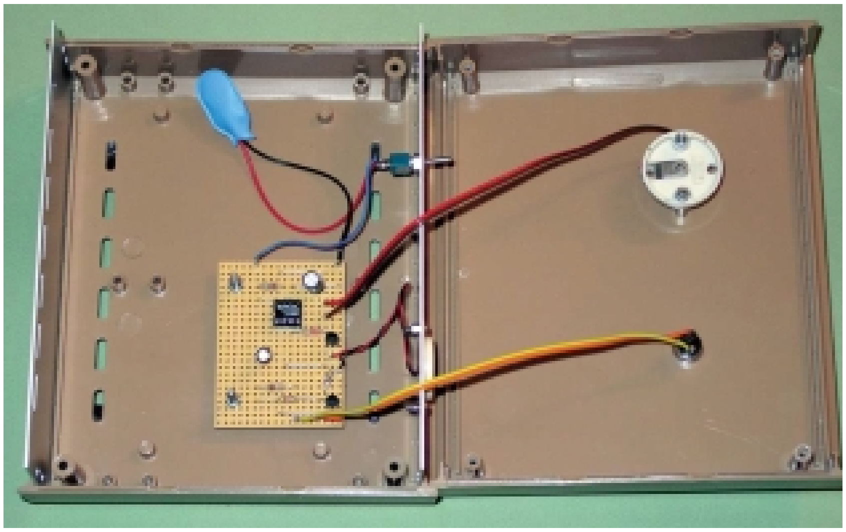
Fitting the light bulb to the case in a reasonably neat fashion is the only awkward aspect of construction. The original intention was to mount the bulb on the top panel using a chassis mounting bulb holder. Some form of transparent plastic cover would then have been fixed over the bulb and holder.

The problem with this method is in finding a suitable cover. The method eventually used was to mount the bulb holder beneath the top panel, with spacers holding it 12·7mm (0·5 inches) beneath the panel. This brings the top of the holder roughly flush with the top panel of the case. A 9mm diameter hole drilled in the top panel enables the bulb to be screwed into the holder.

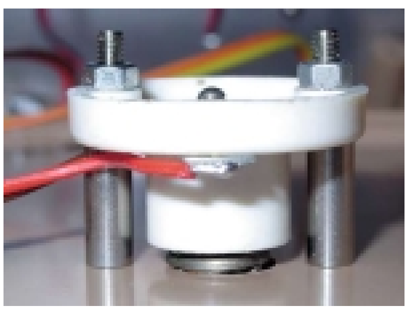
This gives a reasonably neat looking finished article, but it is not very childproof. If small children will have access to the unit it is essential to make access to the bulb more difficult.

One solution is to go for the modern approach, and simply mount everything inside a transparent case. Another possibility is to mount the bulb on top of the main case, but to mount a small transparent case over it. Remember that although access to the bulb must be difficult, it must be possible so that the bulb can be changed.

The small amount of hard wiring is perfectly straightforward. The bulb holder has screw terminals, but you may prefer to remove the screws and make soldered connections to the metal terminal plates. Be careful to connect the battery clip with the polarity shown in Fig.3.



The two halves of the case opened out to reveal the general positioning of the circuit board and the interwiring to the front and top panel mounted components. Don't forget to leave plenty of room for the battery.



Using spacers to mount the bulb holder on the underside of the case lid, above a 9mm diameter hole to allow the bulb to be screwed in from the outside.

TESTING

When the completed unit is first switched on it is likely that it will be triggered and the lamp will switch on. Operating push switch S1 should switch the lamp off again, but avoid making too much vibration when operating S1 or the unit will be triggered again.

With the lamp switched off, try tapping the case or clapping gently near the microphone to check that the unit will trigger properly. If there is any sign of a malfunction, switch off at once and recheck the entire wiring, etc.

If all is well, check that the lamp remains switched on for approximately the correct period. Due to component tolerances and slight leakage in timing capacitor C2 there may be a substantial error in the time that the lamp is switched on. Anything in the region of 4·5 to 7 minutes is acceptable.

If the switch-on time is far too long, or the lamp fails to switch off at all, it is likely that the leakage level of capacitor C2 is too high. It must then be replaced with a higher quality component.

Due to its low standby current consumption the Automatic Nightlight can be left switched on all the time, but it is advisable to switch it off during the daytime. Otherwise there is a risk of it being triggered occasionally, causing the lamp to switch on and run down the batteries unnecessarily.

Finished Automatic Nightlight showing the piezoelectric microphone and on/off switch mounted on the front panel. The bulb should be protected against breakage.

CANUTE TIDE PREDICTOR

by JOHN BECKER

A simple tide calculator for paddlers, dabblers, and kings of the sand castle.

King Canute (or Knut) (c.944-1035). Danish king who finally became King of England (after 1016) as well, taking an English wife and maintaining peace and security. A 12th-century legend describes how he rebuked his flatterers by commanding the waves to stand still – in vain of course – to show the limits of his power. The Reader's Encyclopedia.

-=-=-=-=-=-=-

For over ten years, the author had felt that his power over the waves was also severely limited. Not in some megalomaniac sense, you understand, but in trying to write a computer program that would allow him to predict the state of the tide for any of his favorite coastal laze-abouts.

Could he walk out to that rocky point without having to swim? Could he swim in that broad sweeping bay without having a kilometer walk out across sand?

All too often, and too late, he'd found that the answers were negative! What was needed was a device or computer program that would allow the answers to be immediately displayed. Naturally, it would allow predictions to be accurate within minutes – the mechanism of tide movement was, after all, subject to strict laws of nature and thus readily calculable…

Huh! How naive!

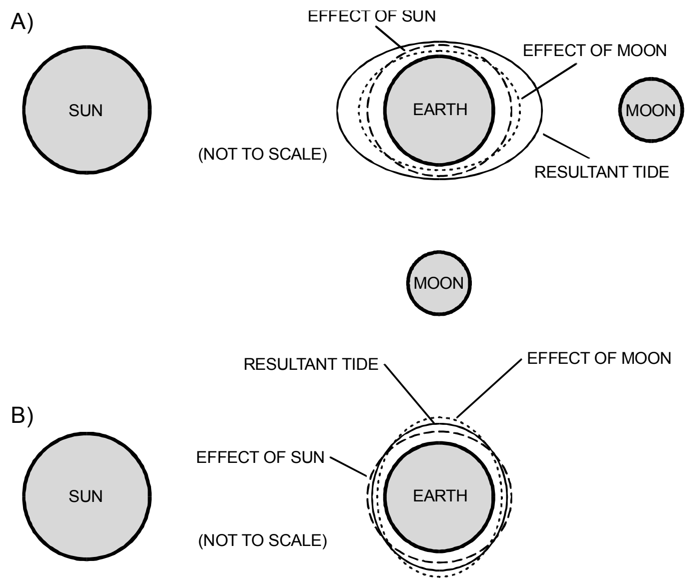


Fig.2. The Sun and Moon both pull on the oceans, their relative angles to the Earth causing different tide heights throughout a lunar month.

LUNACY

We all know (don't we?) that the Moon goes round the Earth and that its gravitational force pulls on Earth's seas and oceans such that they bulge towards the Moon on one side of the Earth's globe, and away from the Moon on the opposite side (Fig.1). We also know that the Earth rotates beneath the Moon, causing the relative positions of the tidal bulges to change accordingly.

Probably drilled into us from childhood is that each day's high tides are about one hour later than the previous day's. Practical experience tells us that there are two tides per day, with about twelve and half hours between them, each caused by one or other of the bulges.

Typically, the rise and fall of the tides is sinusoidal, as illustrated in Fig.1, although there are many local exceptions. Indeed, the author once designed a simple electronic tide predictor that used a tuned slow-speed sine wave generator whose output amplitude was

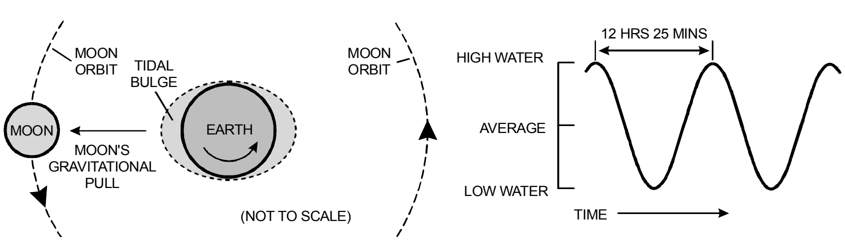


Fig.1. The Moon's gravitational pull causes the oceans to bulge in line with it, resulting in the tide rising and falling over a period of about 12 hours 25 minutes as the Earth rotates.

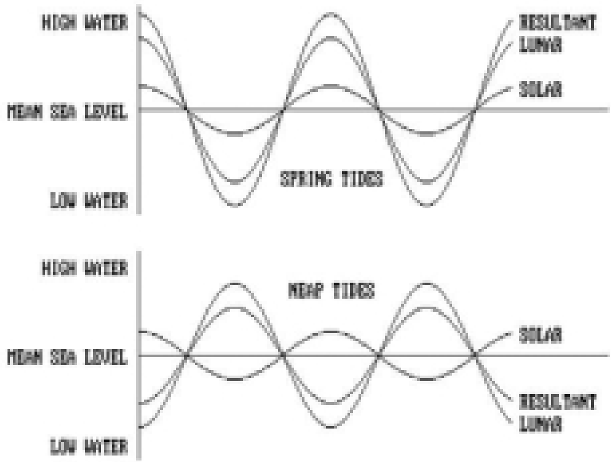


Fig.3. Spring and neap tides are caused by the relative changes of the Sun and Moon positions.

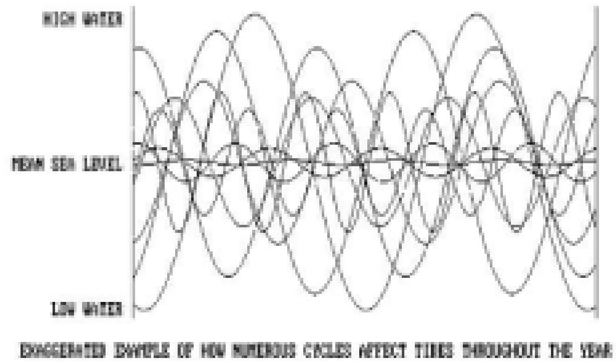


Fig.4. Many cycles other than those directly caused by the Sun and Moon affect tidal ranges. In the compilation of official tide tables, oceanographers could use as many as 115 separate components in their calculations, all having base data that has been recorded by observation over many generations.

displayed on light emitting diodes. (This was published in PE July '92, and is no longer available).

Although the device had limitations, it provided an approximate guide to tide conditions at any preset location. As recently as October '98, a reader in South Africa, Johan van Rooyen of Cape Town, told the author that he still used this tide meter and found it successful. He went on to suggest, however, that it should be updated to use a microcontroller and consume less battery power.

There are several key words in the last paragraph – limitations, approximate and preset location. It was those factors that the author had already been trying to resolve via computer.

NOT TIDE EXACTLY

The problem is that although the average period between tides can be tied down to a value of about 12 hours and 25 minutes, there is a daily difference that varies on a cycle. In fact, it varies according to several cycles. The principal one is caused by the Sun also having an influence on tidal movement, it too causing tidal bulges on opposite sides of the globe.

In Fig.2a are shown the tidal bulges which appear on opposite sides of the Earth when the Sun and Moon are in line with it – their gravitational pulls adding together to increase the height of the bulges. In Fig.2b is shown the situation when the Sun and Moon are at right angles to each other with respect to the Earth – their gravitational pulls tend to cancel out and so the bulges are less pronounced.

This is why relative tide height ranges change throughout a lunar month, spring (very high) tides when the Sun and Moon are in line with the Earth, neap (very low) tides when they are at 90 degrees (right angles) to each other, see Fig.3. Springs occur just after every full and new moon, typically between 36 and 48 hours later. Neaps occur when the Moon is in the first or third quarter.

The height of spring tides varies with the seasons. Those nearest the equinoxes (21 March and 21 September), when day and night have equal length, are somewhat higher.

Because it takes longer for a volume of water to sweep up and down over a wide tidal high-low range than over a narrow range, so the period between the tides changes according to the Sun and Moon positions. Here, then, is the cause of the first deviation from the nominal 12 hours 25 minutes tidal period.

TERRAINOSAURUS

Another factor is the terrain over and through which the tidal mass has to travel. This has the effect of slowing or increasing the rate at which the tidal current flows back and forth.

Many other factors also affect the rate of tidal change. For example, river estuaries heavily influence the rate at which the tide can rise and fall, not only because

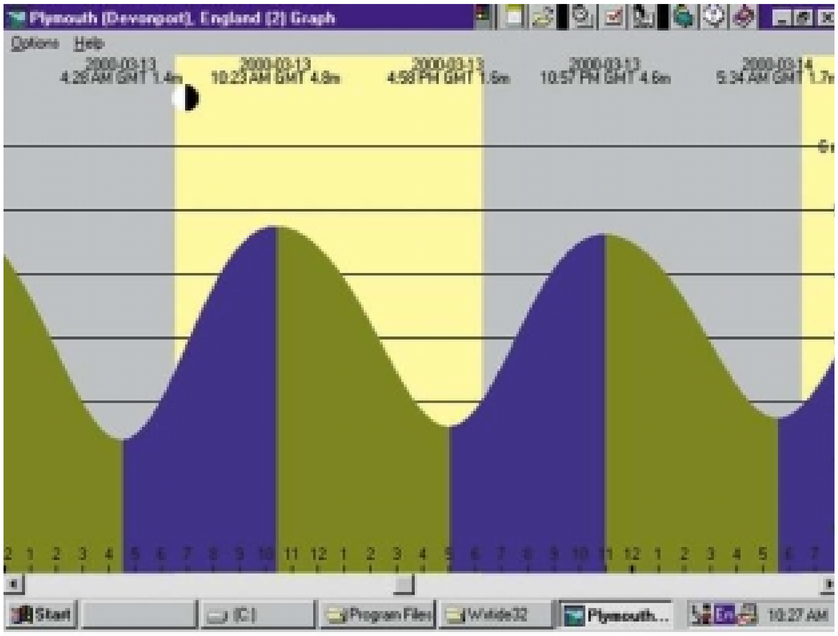


Fig.5. Screen dump of the tidal predictions made by web-based WXTIDE for Plymouth, UK, 13 March '00. Note the half-moon symbol.

of the funneling effect, but also due to the volume of fresh water that rivers carry. An unpredictable factor also becomes apparent when seas and oceans suffer heavy storms, the high winds and abnormal atmospheric pressure causing the water mass to be shifted, resulting in higher tides on the receiving shores.

Nor does the Moon remain at a constant distance from the Earth, which in turn affects its gravitational pull on the tides. The moon's orbit is actually an ellipse, its distance varying from 221,460 miles (perigee) to 252,700 miles (apogee).

A similar factor relates to the Earth's orbit around the Sun, varying from 91,400,000 miles to 94,600,00 miles, with a mean distance of 92,957,209 miles.

OFFICIAL TIDE TABLES

In the UK, the Proudman Oceanographic Laboratories (POL) compute the official tide tables that are quoted in newspapers and other publications.

POL, in their web-based educational demo, state that their predictions can use up to 115 components, each with different frequencies, amplitudes and phases. A screen-dump of a simulation using only a few of the possible components is shown in Fig.4.

Rapidly, therefore, have we moved beyond the simple twelve and half hours tidal period referred to earlier.

Whilst the 115 or so variables can be calculated mathematically, you first need the data which defines them. And here's the rub – the data has been compiled over many generations through direct observation at specific locations, and the data can change as coastal erosion occurs. It is from the observational data that individual cyclic factors are extrapolated.

Some of the data is in the public domain (we shall quote a particularly good web-download source later, a screen dump of one of its prediction graphs is shown in Fig.5). Other data is copyright and needs to be purchased.

WITH THE FLOW

So, realistically, how many variables can be used by a computer program for predicting tides? The answer, in terms of hobbyist software writers, is very few.

Three were used in the author's early experimental PC

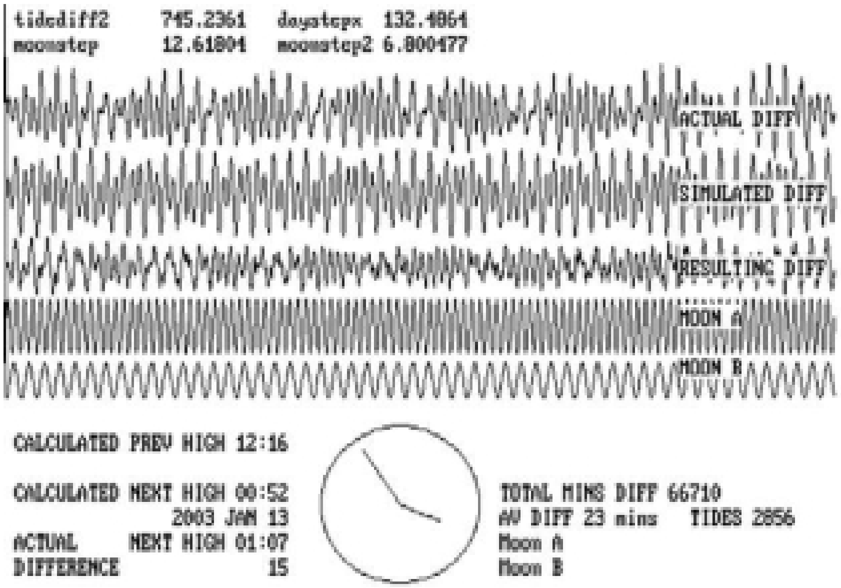


Fig.6. Screen dump of the author's computer-based tide prediction simulation over a 5-year period. The waveforms are explained in the text. it was from this simulation that the Canute Tide Predictor software for a PIC microcontroller was developed.

software, daily Sun and Moon positions on fixed cycles, and a seasonal adjustment for the sun's angle to the equator, also on a fixed cycle.

The simulated tidal predictions were accurate to within about 25 minutes when compared against published official tide tables, which he had acquired over several years.

At the time, the author was unaware that tides were professionally predicted from observed data cycles rather than purely trigonometric values (sine waves, concentric circles, ellipses, parallelograms of forces, etc.).

No matter how hard he coaxed "ze little grey cells" and modified software, greater accuracy seemed unattainable. He didn't know why, and had been hoping to be within about five minutes of official predictions.

After several attempts over the years, he eventually gave up. Until that is, the South African reader offered his encouraging comments. Discussions with Editor Mike, who is a keen sailor, resulted in us concluding that such accuracy was irrelevant to most people. Even he initially only needed to know roughly the time of high or low water in Poole Harbour! Others might only need to know whether to go to the beach in the morning or the afternoon.

Consequently, it was decided that a simple microcontrolled unit with liquid crystal display and an accuracy somewhat less than that originally envisaged would suffice.

MICRO LIMITS

However, whilst the computer program was able to achieve accuracy to within about 25 minutes, the limitations of a small microcontroller prevent a similar accuracy being achieved by an inexpensive small handheld unit. Whereas a PC can store data in many files on disk or in its memory, a microcontroller has limited memory and data storage capacity.

Its processing speed also places a severe limit on how many variables it can process

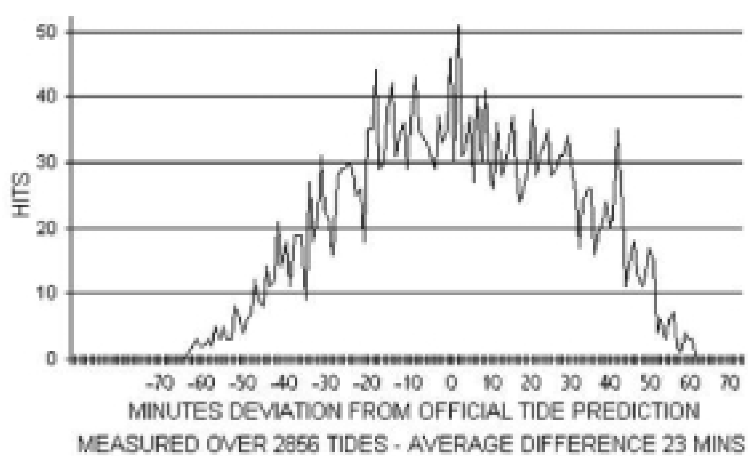


Fig.7. Screen dump of the tide prediction accuracy as calculated by the program referred to in Fig.6 and displayed using Microsoft Excel.

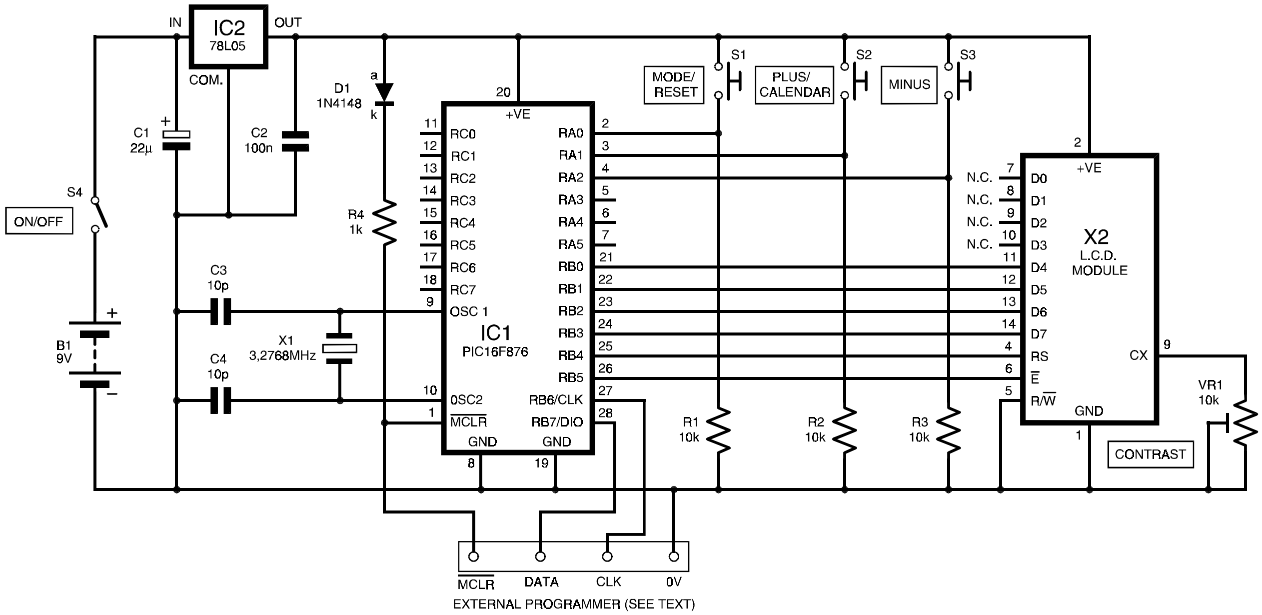


Fig.8. Complete circuit diagram for the Canute Tide Predictor.

while still maintaining accurate time and calendar data, even if the variables were to be held in external memory. The lack of multiplication and division commands on a typical microcontroller also impose processing speed problems.

It was decided, therefore, that only the two main variables, relative Sun and Moon positions, would be used in the basic calculations. In comparison with published tide tables for Plymouth (downloaded from the web), the accuracy of the author's prototype, as described here, remained within about one hour over a simulated five year period, with an average deviation of about 23 minutes, but with many predictions being much closer. A screen dump of the simulation is given in Fig.6.

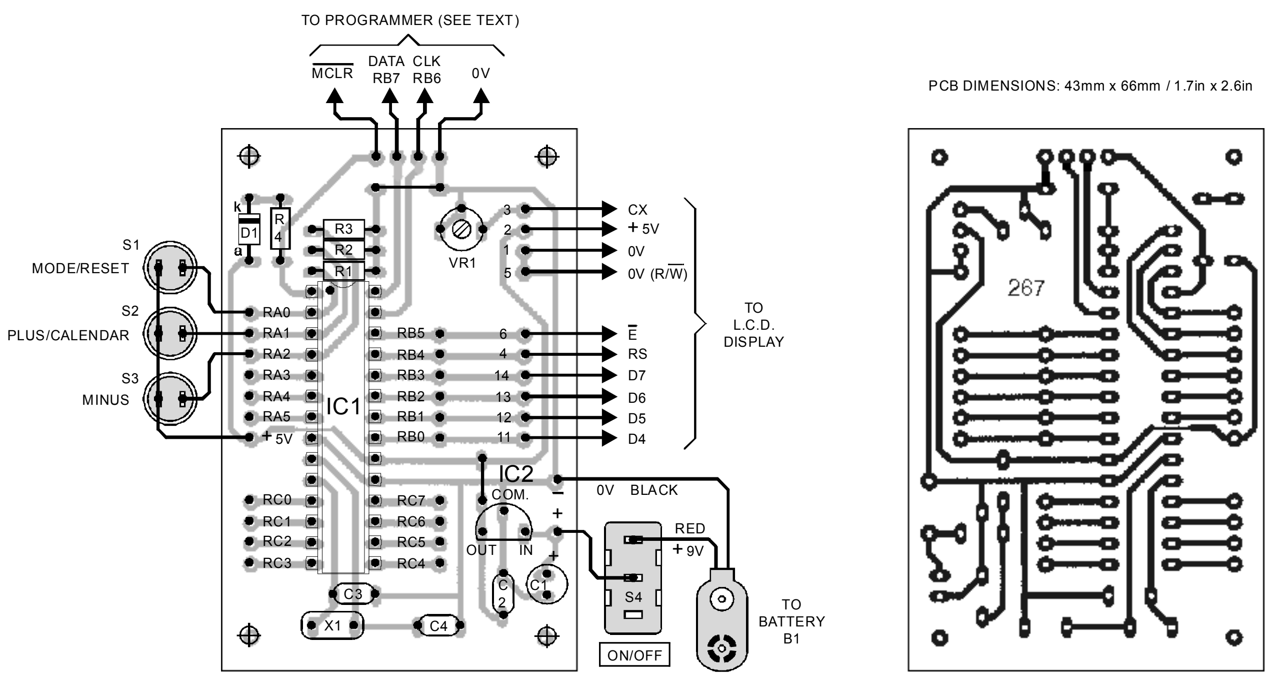


Fig.9. Printed circuit board component layout, wiring to off-board components and (approximately) full-size copper foil track master pattern for the Canute Tide Predictor.

Moon B waveform is the representation of the standard lunar cycle, Moon A represents the spring and neap tide cycle as caused by the relative angles of the Sun and Moon.

Although it may not be apparent from Fig.6, the Moon A and Moon B waveforms are sinusoidal, Moon A running at a cycle rate of just under twice that of Moon B (a ratio of 12·61804 to 6·800477) the amplitudes of the two waveforms are also precisely related, as are their initial phases.

The Actual Diff waveform is drawn from the downloaded tide values being pulled in from disk. The Difference being that between the basic 745.2361 minutes between tides, and that which actually exists. The Simulated Diff waveform is the sum of Moon A and Moon B, which is compared with the Actual Diff to produce the Resulting Diff. Had the Actual and Simulated Diffs been exactly matched, the Resulting Diff would be shown as a straight line.

Five years of tides (2856) are represented. A cumulative total of the Resulting Diff shows a value of 66710 which is divided by the tide count to produce an average difference of 23 minutes.

The "clock" is an animation illustrating the angles of Moon A and Moon B at any moment during the simulation.

The graph in Fig.7 illustrates a summary of this simulation. Horizontally, the graph shows the minutes deviation from the downloaded prediction. Vertically, the number of "hits" on the minutes of deviation are recorded.

CIRCUIT DIAGRAM

The *Canute Tide Predictor* is based on software embedded into a PIC16F876 microcontroller. This device, as discussed in previous *EPE* articles, has 8192 bytes of program memory available, 368 bytes of data RAM and 256 bytes of EEPROM data storage. The software will be discussed later.

First, let's quickly describe the *Canute Tide Predictor* circuit diagram, as shown in Fig.8, and the unit's construction.

The PIC microcontroller, IC1, is operated at 3.2768MHz as set by crystal X1. There are three pushbutton switches, S1 to S3, which control several functions, as discussed when the software is described. The switches are connected to Port A pins RA0 to RA2, which are normally biased low via resistors R1 to R3.

Data is output to the liquid crystal display (LCD), X2, which functions in conventional 4-bit mode. Its screen contrast is adjustable by preset VR1.

The option to program the PIC yourself is made available via the ~MCLR, Data (RB7), Clock (RB6) and 0V connections. Diode D1 and resistor R4 allow a 12V to 14V programming voltage (Vpp) to be fed to the ~MCLR pin, with the rest of the circuit being unaffected. This is in keeping with other *EPE* PIC projects, which can be programmed using PIC Toolkit Mk2 (May-June '99).

The pin order and spacing of the LCD and programming connections on the printed circuit board (PCB) are the same as that used by the author on his other recent PIC constructional projects.

Power to the design can be from a PP3 9V battery (B1), with regulator IC2 dropping the voltage to 5V, as required by the PIC and the LCD. Component S4 is the power on/off switch. Current consumption is just under 6mA.

Power may alternatively be supplied by a mains operated 9V battery eliminator (adapter) via a suitable socket.

It will be apparent that this circuit can be used as the base for a wide variety of other PIC16F876 (and '873) controlled applications, for which other software can be written. The PCB has been designed with this in mind, with access connections available to make use of Port C and the unused pins of Port A.

It may also be of interest to know that although the author used a PIC16F876, this was because he had them in stock. The PIC16F873 may be used instead. Furthermore, the software can also be run on the PIC16F874 and '877 without modification, provided that the PCB is redesigned to accept these larger devices. (Much of the original prototype software evaluation was done with an existing board designed for the '877.)

The software is not suitable for running on other PIC devices. It is too lengthy and has too many variables to be run on the PIC16x84, for example. The program is around 2000 commands long.

CONSTRUCTION

Details of the PCB component and track layouts are shown in Fig.9. This board is available from the *EPE Online Store* (code 7000267) at **www.epemag.com**

Use a socket for IC1 and

COMPONENTS

Resistors
R1 to R3 10k (3 off)
R4 1k
All 0.25W 5% carbon film or better

Potentiometer
VR1 10k miniature round preset

Capacitors
C1 22u radial electrolytic, 16V
C2 100n ceramic disc, 5mm spacing
C3, C4 10p ceramic disc, 5mm spacing (2 off)

Semiconductors
D1 1N4148 signal diode
IC1 PIC16F876 pre-programmed microcontroller (see text)
IC2 78L05 +5V 100mA voltage regulator

Miscellaneous
S1 to S3 miniature push-to-make switch (3 off)
S4 miniature s.p.s.t. or s.p.d.t. toggle switch (see text)
X1 3.2768MHz crystal
X2 16-character, 2-line alpha-numeric liquid crystal display

Printed circuit board available from the *EPE Online Store*, code 7000267 (**www.epemag.com**); 18-pin DIL socket; terminal pins; case 150mm x 80mm x 50mm; 9V PP3 battery and clip (see text); connecting wire, solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only **$38**

assemble the components in any order you feel comfortable with. Ensure the correct orientation for IC1, IC2, D1 and C1. Off-board connections are also shown in Fig.9. The use of 1mm terminal pins is recommended for these.

The LCD may be supplied in one of two pin configurations, as given in Fig.10. The top configuration in Fig.10 is the one used by the author. This device was supplied with a ready-fitted connector which matches the

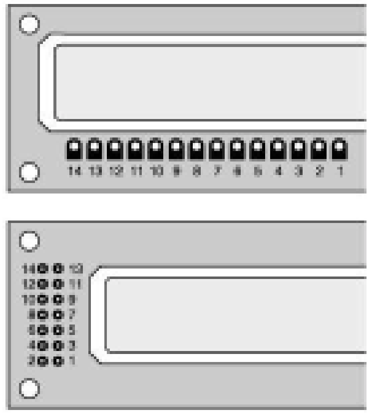


Fig.10. Pinout arrangement of the two basic LCD formats.

pin order on the PCB (see **Shoptalk**).

The plastic case used for the prototype is larger than actually needed and a smaller one of suitable dimensions could be used instead. The cut-out for the LCD can be made by drilling holes within the perimeter of the screen area, cutting or sawing between them, and then smoothing with a file. (Why on earth doesn't any manufacturer make plastic cases with the correct sizes of cut-out for standard alphanumeric LCDs – anyone know an answer?)

PROGRAMMING THE PIC

Details for obtaining the software (which is available for free download from the *EPE Online Library*), and preprogrammed PICs, are given in **Shoptalk**.

The initializing configuration required by those programming their own PICs is the *PIC Toolkit Mk2* default of Table 1:

Note that in common with a few other readers, the author has encountered what seems to be a bug in the PIC16F876. Under some programming circumstances (and they have not yet been established), the PIC can have one or more of its Code Protect flags undesirably set. It does not happen on every occasion.

The problem has been experienced by readers using several different types of PIC programmer. On the *PIC Toolkit Mk2* programmer the problem is revealed when the verification process (if active) states that masses of errors have been encountered.

The author found that, despite this message, the PIC had been correctly programmed. Consequently, unless you know that you have made a mistake (as listed on the error-reporting screen), you can probably assume that your device is correctly programmed. The truth of the matter will become apparent when you run the PIC in circuit.

Feedback is requested from readers who have experienced this code-protection problem, and brief details of the conditions under which it occurred.

PROGRAM OPERATION

Before first powering up the Tide Predictor, press Mode/Reset switch S1 and keep it pressed while you switch on the power, S4. Assuming that you have made no assembly errors, you should see the screen activated for two lines of data stating:

Table 1

CP1	CP0	DBG	NIL	WRT	CPD	LVP	BOR	CP1	CP1	POR	WDT	OS1	OS2
1	1	1	1	1	1	0	0	1	1	0	0	0	1

Adjust preset VR1 until a reasonable image contrast is seen.

At switch-on, with Mode/Reset S1 pressed, the program resets all data to default values as written into the code. The data is copied into some parts of the EEPROM memory and some into the working variable registers.

LOOK-UP TABLES

Look-up tables for month and weekday names (abbreviated) are copied into EEPROM at known addresses, easing and speeding their future access. The time and calendar data for the instant that the year 2000 commenced is also stored.

Also stored in EEPROM are the values of the two variables used in the simulation of the Sun and Moon positions. These relate to tidal conditions at an imaginary location (but probably not far from Plymouth, Devon, UK) at that moment in time.

They have been calculated as preset values such that without further time correction a high tide occurring at 00:59 would be predicted. It is from these base values that all future tide predictions are calculated, irrespective of location and local time.

Release Mode/Reset S1. The screen will now display:

Note the flashing asterisk under the year 00. Using either push switch S2 or S3, the year value can be incremented or decremented. Press S1 to move the asterisk below the A of JAN, and the SET YOUR DATE message disappears. The month value can now be changed using S2 or S3.

The process is repeated for each of the other date and time factors. Once the hour value has been set and S1 pressed again, the tide prediction calculation is performed and the lower LCD line will be similar to:

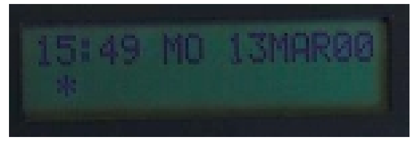
where the asterisk is again flashing and the time of the next high tide will be seen for the date you have set for the imaginary location referred to above.

You now need to refer to published tide tables in order to find out the actual high tide predicted officially for that date and following the basic clock time you have set. More details on finding such facts are given later.

The program allows the tide time to be increased or decreased in steps of six minutes, again using S2 or S3. The time is according to a 24-hour clock and rolls over appropriately depending on whether the value is being increased or decreased. Set the time for your next high tide.

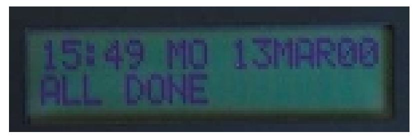
Press S1 (Mode/Reset) again to change the lower line to read:

FAST/SLOW *+0000



This allows the real-time clock to be corrected to run faster or slower should the PIC's system clock not be running spot-on. You may not know for a few days whether or not it needs adjusting. Leave the value at zero for now.

Again press S1, causing the lower line to display the ALL DONE message:



Between you pressing S1 and this message appearing, the new data is stored in EEPROM and will stay there until you change it again, even when the Tide Predictor is switched off.

TIDAL BARGRAPH

With the ALL DONE message now displayed, pressing S1 again puts the Tide Predictor into its normal running mode.

On the top line is shown a bargraph, the darkened pixels indicating the current state of the tide. At the right of the top line will be seen either a ">" symbol, indicating that the tide is rising, or a "<" symbol indicating a falling tide.

The terms rising and falling should be treated loosely. What they mean here is that the predicted time is either still being approached, or that it has been passed. In reality, of course, the

changeover between a tide rising and it falling is not instantaneous. There is a period known as slack water when it is doing neither of these things, and no tidal currents are flowing at that location.

The slack period varies according to location and the season, but a period of half an hour is not uncommon.

Each LCD character cell (of which there are 16 per line) represents 30 minutes. Each cell has five columns of pixels, each column representing six minutes. After each group of six minutes, the display changes to show the appropriate number of darkened columns, increasing or decreasing according to the tide direction.

There is no fixed column number that indicates high or low water. As soon as the high or low water prediction time has been reached, the graph reverses direction at that point. In time you will recognize that this can give an indication of the height of tide extremes (in a relative sense, since actual tide height prediction in meters or feet is not possible without access to the data from which official sources calculate their tides).

Practical limits had to be set in the program to prevent extreme groupings of tide movements from trying to overshoot either end of the LCD. The graph will not exceed cell 15, nor go lower than column one of cell one. For the most part, the graph movement will be confined to well within these extremes.

NUMERIC DATA DISPLAY

In line two of the display are three numeric values. The center value shows the current time, the colon flashing at a one second rate.

At the right is shown the time of high tide. When the tide is rising (> symbol), the time is that of the next predicted tide. When the tide is falling (< symbol), it is the time of the high tide that has passed. It only changes its value when the tide has fallen to its predicted low and starts to rise again.

On the left of line two, the value is the time of low tide, either that being approached (< symbol) or the one that has passed (> symbol). The value only changes when the predicted high tide time has been reached.

Note that when the Tide Predictor is first switched on and the tide is calculated to be rising, only the time of the next predicted high tide is shown, with four question marks (????) being shown in the low tide time position.

Conversely, if the tide is falling, the four question marks will be in the high tide position, but with the next low tide time being shown in its own position. The next high tide will be shown after the low tide time has been reached.

Otherwise, the low tide value is only calculated and shown when the high tide turns and begins to fall.

CALENDAR DISPLAY

At any time during normal running, switch S2 (Plus/ Calendar) can be pressed. The display then shows time and calendar data on its lower line. The upper line continues to show the tidal bargraph.

Pressing S2 again returns line two to the prediction times display.

ADJUSTING DATA

All timing factors may be adjusted during running. To enter adjustment mode, press Mode/Reset switch S1. The screen will then display the same set of changeable data as described earlier.

Any of the factors may be changed as before, simply pressing S1 to move between them. Again when all values have been changed as required, high tide prediction is calculated and all the data restored in EEPROM.

All calculations are made from the original reset default values (00:00 01JAN00) and you may “turn back the clock” if you need to.

POWER OFF

You may not wish to keep the Tide Predictor permanently switched on, and to avoid you having to fully reset all the calendar facts from 00JAN00, the data held in the EEPROM is updated at each high tide rollover.

This means that should you switch off and restart again at a later date, you only need to update from the last set of data stored before switch-off.

PIC CLOCK

The PIC's internal clock is set so that a clock updating routine is accessed at nominally once per second. However, the controlling crystal does not necessarily oscillate exactly at its stated rate of 3·2768MHz but is subject to a manufacturing tolerance. To compensate for this, the fast/slow adjustment referred to earlier has been included.

Thus it is not exactly one second which is added to the clock each time the routine is accessed, but a value that can be set fractionally greater or smaller than this.

A 3-byte hexadecimal value is repeatedly added to an intermediate 3-byte counter, each time the counter rolls over to zero, so the seconds counter is incremented. As expected, the minutes counter is incremented every 60 seconds! The rest of the time and calendar data is updated as appropriate, including allowance for leap years.

When adjusting the fast/slow factor, each unit of change shown on screen represents one second change per 4,194,304 seconds. There are approximately one million seconds in 11·5 days, so the potential for clock-setting accuracy is good. (By using a 4-byte counter, the ratio could have been programmed so that each unit of adjustment represented one second per 2,147,843,648 seconds!)

CALCULATIONS

As stated earlier, tide predictions are made according to the relative angles of the Sun, Moon and Earth. On their own, these cycles do not take into account local time. For this data a third angular value is used, representing the 24-hour clock cycle, which can be set to suit any time zone.

The angular positions are simulated by using three hexadecimal counters to which fixed values, having several decimal places of accuracy (in hexadecimal notation), are periodically added. Tidal predictions are made according to the relative angle counts. The process is simple in principle, but complex in terms of the program commands required. It is beyond the scope of this article to describe how the results are achieved.

It is relevant, though, to quote the values that are used as the basis for the simulation:

The average difference between tides has been calculated according to the period of the Lunar Synodic Month (LSM), given in the Astronomic Constants Index (more details later) as 29·5305888844 days. From this, the average period between successive tides has been calculated as 745·2361 minutes, which equals 12 hours 25·23606 minutes – a value not too far off from the approximate value quoted earlier.

From the same source, the value for Earth Rotations per Lunar Orbit has been taken as 27·39646289 days. It is a sub-division of this period that is used to "modulate" the value of the LSM cycle to simulate the differing angles between Moon, Sun and Earth when prediction calculations are made.

The 24-hour clock angle, by fortuitous convention, rotates in a period of 24 hours!

These three values are subdivided within the program such that the three circular motions have their angles appropriately increased on each occasion that the LCD clock value matches that of the predicted high tide time.

From the resulting angular relationships, the times of the next high and low tides are

PANEL 1 – WHERE DOES IT GO?

It was when considering tidal constants for different locations that the author recognized an unexpected significance about them. Because the Earth is rotating beneath the Moon and sun, it would seem reasonable to assume that the respective tidal bulges must remain at the same relative angle to them.

Thus, at the equator, the tidal bulge should travel a little over 1000 miles per hour (the circumference of the Earth being approximately 25,000 miles). At the latitude of Land's End (about 50°N) from the equator, a rate of about 330 MPH might be expected. From this, high tide at Dover should be a little under one hour earlier than at Land's End (about 350 miles west of Dover).

The reality is vastly different, as examination of tidal constants shows (and experience confirms – when did you last see a 330 MPH tidal wave travelling up the English Channel?). In fact, the difference between high tide at Dover and Penzance (not far from Land's End) is about six hours.

So what causes a slower tidal front than logic would suggest, and what happens to the water that should be tracking the gravitational pull of our celestial neighbors? The author does not know. Answers addressed to *Readout* please!

calculated. The next low tide time is immediately shown and the tide rising symbol changes to tide falling.

No change is made, though, to the high tide time already displayed. This now represents the time of the last high tide. For the moment, the newly calculated high tide value is simply stored.

About six (or so) hours later, when the LCD clock value matches that of the low tide prediction, the stored high tide value is displayed, along with the tide rising symbol. The existing low tide value still on display is now regarded as the time of the previous low tide.

Between the instants of tide recalculation, the bargraph display is repeatedly updated to give a visual indication of the current tide state.

USING THE TIDE PREDICTOR

Earlier we described how the various time and date values could be changed. There is little more to using the Tide Predictor than that. In whatever part of the world that you live, providing that you can initially find out the high tide time for your preferred coastal location when first setting up the data, you can use this handy predictor.

Originally, it had been hoped to include the option to have the "tidal constants" for several locations to be programmed in and selectable. Sorry, but the author has decided the additional programming involved would keep him indoors away from the sea this summer. Perhaps one day…

However, there is a simple solution you can use. Set up the Tide Predictor for your favorite location, and from the same source that you obtained its tide time data, also note the tide times for other locations on the same day.

Now work out and write down the time difference between your primary location and the others, to the nearest half hour perhaps. All you need do then is use a bit of simple mental arithmetic to predict tides for other locations from the primary value displayed on screen.

Should you ever feel the need to start the predictions again from zero, press switch S1 while switching on power using S4 (as described earlier).

PROUDMAN OCEANOGRAPHIC LABORATORY

The Proudman Oceanic Laboratory (POL) is the UK's official tide prediction organization. Their Bidston Observatory is a recognized climatological station, reporting to the UK's Met Office at Bracknell.

POL has an excellent web site at **www.pol.ac.uk** and there are tutorial demos available for free download that illustrate the causes of tides and changes in the weather. A demo version of the POLTIPS tidal prediction software can be downloaded as well (the full version may be purchased). The site has links to other global tide prediction agencies.

A 58-page brochure detailing other facilities offered by POL can also be downloaded.

Records going back to 1845 are held by POL. For 125 years the readings were obtained by manual observation. Today they have an automatic weather logger that takes readings every three seconds.

PANEL 2 – VITAL NOTE!

The *Canute Tide Predictor* has probably been one of the most challenging software controlled designs the author has ever produced (being preceded by a decade of programmed experiment!). The code routines have been difficult to write, but they seem to produce realistic values when compared against published tide tables.

However, the accuracy of the predictions cannot be guaranteed, even within the range stated earlier. There may be some combinations of angular values that the software does not handle correctly. Should you discover any, please tell the author the exact date, time and correction values when the error occurred, together with the original factors last programmed in via the switches.

DO NOT RELY ON THIS DESIGN'S TIDE PREDICTIONS FOR ANY SITUATION WHICH MIGHT ENDANGER LIFE. If you really need to know exact tide times, always ask the local Coast Guard and advise him of where you are going and when you expect to be back.

In his scuba-diving days, the author and fellow B.S.A.C. members used to be on CB-radio standby with our inflatables for the Coast Guard and R.N.L.I. in case of an in-shore waters emergency near our diving location. We responded on several occasions and know how important it is that people should be aware of tide and weather conditions when putting to sea in small boats or walking along shores where rising tides can cut off retreat.

There are occasional Open Days for which you can obtain free entrance tickets. This year (2000) the dates (as downloaded 10 March) are 4 June, 29 June, 7 July. Apply to Open Day Tickets, Proudman Oceanographic Laboratory, Bidston Observatory, Bidston Hill, Bidston, Prenton CH43 7RA, UK.

Tel: +44 (0) 151-653-8633

Fax: +44 (0) 151-653-6269

WXTIDE

A really superb and highly interesting web site is that which can be accessed at **www.geocities.com/SiliconValley/Horizon/1195/wxtide32.html** (pointed out to the author by South African reader Johan van Rooyan). From this site tide prediction software (WXTIDE32), which probably has data for thousands of locations world-wide, is available for free download. The latest version 2.6 is 1·38Mb. An earlier version was heavily used in the final stages of designing and verifying this Tide Predictor.

The global locations offered, and preferences for the way in which data can be displayed, are available via drop-down menus. Some typical screen dumps are shown in Fig.5 and Fig.11.

Gratitude is expressed to Dave Flater, whose site it appears to be, and to all those who contribute to the site, which is well presented and maintained. There are also many links to other tide-related sites (plus some covering tornadoes, of which there are amazing photos that can be pulled in).

PANEL 3 – TIDAL HISTORY

The first tide predicting machine was invented by Lord Kelvin in 1872. He knew that tidal patterns could be modeled using sine waves, and that a sine wave can be represented by the motion of a wheel that has its shaft off-center (eccentric).

Kelvin used several different eccentric wheels, linked by a single wire around each of them along the machine. The combined effects of the up and down motion of the wheels resulted in a single up and down movement at one end of the wire to which a pen was attached, this movement simulating and illustrating tidal behavior.

Arthur Thomas Doodson (1890-1968) used this principle to help calculate the exact tides for the D-Day landings in 1944, having constructed a 42-variant version. It took this machine a day and a half to calculate the tides for one location for a year. Until computers took over, this machine remained the best in the world for tide prediction.

Doodson originally started work in Liverpool on tide prediction in 1919, ultimately making it his life's work. He and a certain Mr Proudman (of whom no more details are known) was instrumental in starting the Tide Institute at Birkenhead (now POL, named after Mr Proudman). Interestingly, a source name quoted on one POL document in 1999 is Valerie Doodson, presumably his descendent.

ASTRONOMICAL CONSTANTS

The Astronomical Constants Index was downloaded via **www.geocities.com/Athens/Olympus/4844**. There are other related (and unrelated) downloads offered, including some fascinating material on archeaogeodesy ("that area of study encompassing prehistoric and ancient place determination…"), and astronomy in general.

James Q. Jacobs runs this

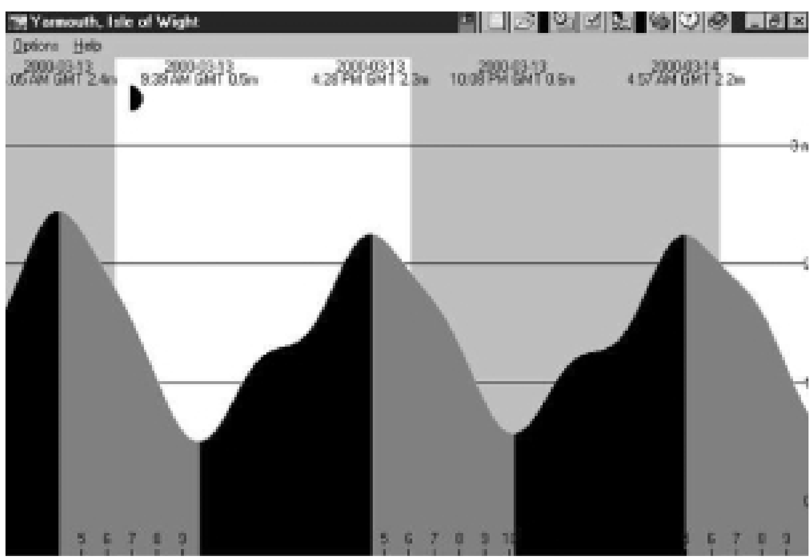


Fig.11. not all tidal movements seem sinusoidal. This screen dump shows a double-humped pattern for Yarmouth, Isle of Wight. The Canute Tide Predictor does not attempt to match such waveforms.

TIDE LINES

330 BC. Greek explorer Pytheas, on reaching the Baltic Sea, observes strong tides and theorizes that they are caused by the Moon.

1609 AD. First attempt is made to harness tides in the Bay of Fundy as a source of power for small mills.

site and it's well worth browsing in depth. He tells us, for example, that in a translation of the work Aryabhatiya of Aryabhata, An Ancient Indian Work on Mathematics and Astronomy the following is written:

"In a yuga the revolutions of the Sun are 4,320,000, of the Moon 57,753,336, of the Earth eastward 1,582,237,500, of Saturn 146,564, of Jupiter 364,224, of Mars 2,296,824, of Mercury and Venus the same as those of the Sun."

James believes that these are oldest exact astronomic constants known. He has calculated that Aryabhata's ratio would have been exact in 1604·4 BC, at which time there were 366·2563565652 Earth rotations per solar orbit. Astonishing accuracy! Especially so when you consider that the astronomic constant for 1 Jan 2000 was recently calculated by sophisticated modern equipment to be 366·25636031 rotations. The Earth's orbit (one year) is currently 365·25636053 days. It is not known how the concept of a "yuga" was perceived.

OTHER SITES

The BBC web site at **www.bbc.co.uk/education** has links through which you can discover many things about science and technology, and gain access to related sites.

The UK Meteorological Office site is at **www.meto.gov.uk**

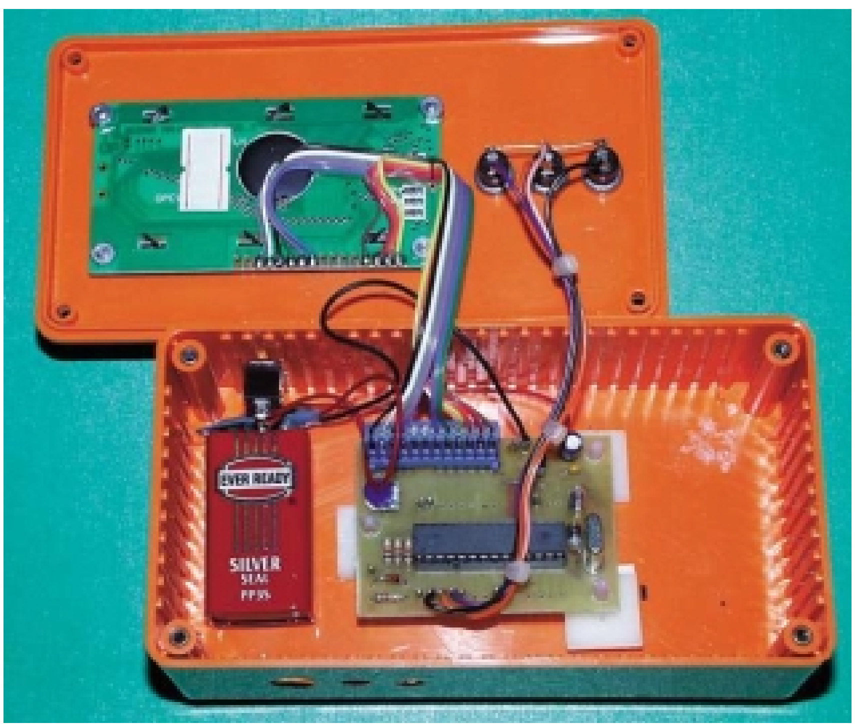
The equivalent US site (National Oceanic and Atmospheric Administration) is at **www.noaa.gov**

OTHER SOURCES

Other sources of tidal information are:

- o) Old Moore's Almanac (a worthy source for such down-to-earth information), is often available from newsagents. It quotes high water data for London Bridge, plus corrective tidal constants for a few other UK locations. It also quotes dates and times for the moon's phases, and for sunrise and sunset.
- o) The Times, which quotes daily high tide times and heights for many locations around the UK.
- o) Annual tide prediction tables for local regions are available as handy-size booklets from yacht chandlers around the UK, and from some newsagents. These too give tide heights as well as times. Tidal constants for nearby locations are also given.
- o) The Coast Guard – see your local telephone directory. Dial 999 (in the UK) in case of emergency.
- o) Posters along beach resort and harbor promenades.

Regrettably, the Automobile Association has long since stopped publishing tidal data in its Members' Handbook.



Canute Tide Predictor mounted in its case. Note that the prototype PCB differs slightly from the published version.

MULTI-CHANNEL TRANSMISSION SYSTEM by ANDY FLIND

Linking the signaling system together. Plus, extending its versatility with a simple Interface add-on.

Last month's issue featured the design and construction of a communications and signaling system providing up to sixteen channels in both directions through a two-wire circuit. There are a number of ways in which the Transmitter and Receiver modules of this system can be used so these will now be described.

Some applications require only the two boards from last month, but for more demanding applications additional interface modules can be used to process the communicating signals. The construction and use of this add-on Interface will be covered later.

ONE-WAY ONLY

As we outlined last month, the system can provide either eight or sixteen channels, in a single direction or both ways. To begin with, some simple one-way configurations will be described. These require only two modules, a Transmitter and a Receiver.

For eight channels only IC1 (one PIC) will be needed in each module, whilst sixteen channels will require the fitting of IC2 on both boards. An eight-channel system can be easily upgraded at a later date by adding the extra ICs as no other additional parts are required. Also, if only one board has IC2 fitted the system will still operate correctly with eight channels.

The simplest method of connection has already been described in the testing procedure given last month. If the wiring between the Transmitter and Receiver has three cores this method can be used, although the "common" connections of the modules may be used for "ground" (0V) if preferred as shown in Fig.12. For this method of connection none of the optional components are needed on the boards.

Where power is available at both ends of the system only two wires are needed to implement the transmission. If a 5V supply is available for the Transmitter it can be powered directly from this. Alternatively, the regulator IC3 can be fitted to

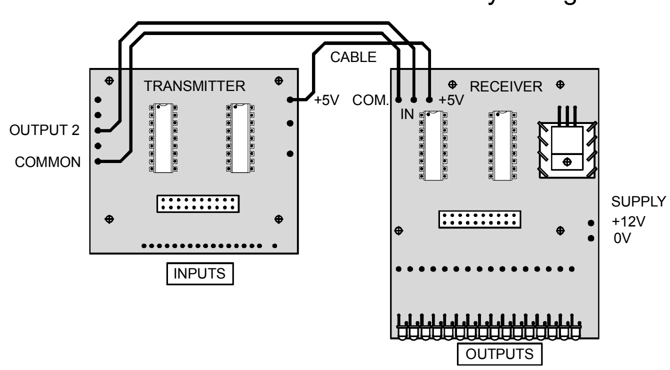


Fig.12. Setup for a three-wire connection.

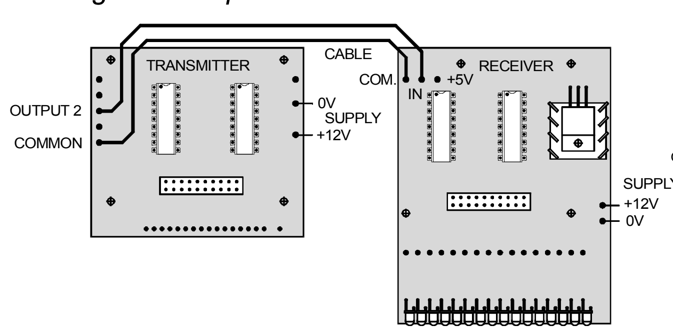


Fig.13. Two-wire connection, with separate Transmitter power supply.

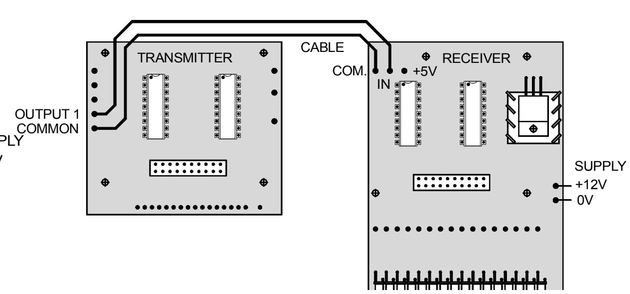


Fig.14. Two-wire set-up, with Transmitter module powered from the Receiver.

it together with extra decoupling capacitors C6 and C7, which allows operation from supplies of 9V to 20V. The supply current taken will be just 2mA to 3mA. The method of connection between the two units is shown in Fig.13.

A third method allows the Transmitter to be powered by the Receiver again, but this time using only two connections between them as shown in Fig.14. For this resistor R10 should be fitted to the Receiver. At the Transmitter resistors R1 and R5, diode D1 and transistor TR1 will be needed.

The two common connections on the boards should be linked and Output 1 of the Transmitter should be connected to "IN" of the receiver. This connection takes a positive 5V supply to the Transmitter and also carries the signal when pulsed low by the transistor.

ON THE DOUBLE

The next method of connection requires two Transmitters and two Receivers as it is a two-way arrangement using the Transmitters' ability to synchronize to each other and send their data by turns. It was not originally intended that they should be used in this way as two-way operation was to be effected through two of the Interface modules, which will be described shortly.

However, it works well and can be achieved with very few extra components, and since some constructors will undoubtedly have suitable applications it is shown in Fig.15. It is assumed that for two-way applications a power supply will always be available at both ends so each Receiver is powered by a supply of between 9V and 15V, and the 5V regulated supplies from them power the two Transmitters.

The common points of all four modules are connected together through one of the two wires of the transmission circuit. The other wire has a 2·2 kilohms (2k2) pull-up resistor to the 5V supply at each end so that it is normally pulled high through a resistance of about 1k.

Each Transmitter has a 1N4148 diode from the Output 2 connection to this wire, which is used to pull it low to transmit data. The Receiver "IN" points are connected to the line through 10k resistors and also have connections to the Sense/ Mute points on the Transmitters, allowing each transmitter to check that the line is inactive and mute the local Receiver before sending data to the distant one.

This arrangement requires none of the optional components on the boards and draws a supply of about 10mA at each end. It can have either eight or sixteen channels or even eight channels in one direction and sixteen in the other. However, the two Transmitter IC1s should have different delays in their programs, achieved by using TXIC1_5 software at one end and TXIC1_10 at the other, to ensure that they always synchronize correctly.

INTERFACING

There will be some applications, such as that for which this project was originally developed, where a 5V peak-to-peak digital signal will be unsuitable for the circuit through which the boards are to be linked. Telephone lines are an example of this. Whilst, for legal reasons, this project should ***never*** be connected to the ***public*** telephone service, it may find uses in premises with *private* internal telephone systems.

Square waves with a peak-to-peak amplitude of 5V are not suitable for these as they will probably cause interference to other users through stray coupling in the wiring and they might even damage or disrupt the system. Another problem which could arise where long connecting lines

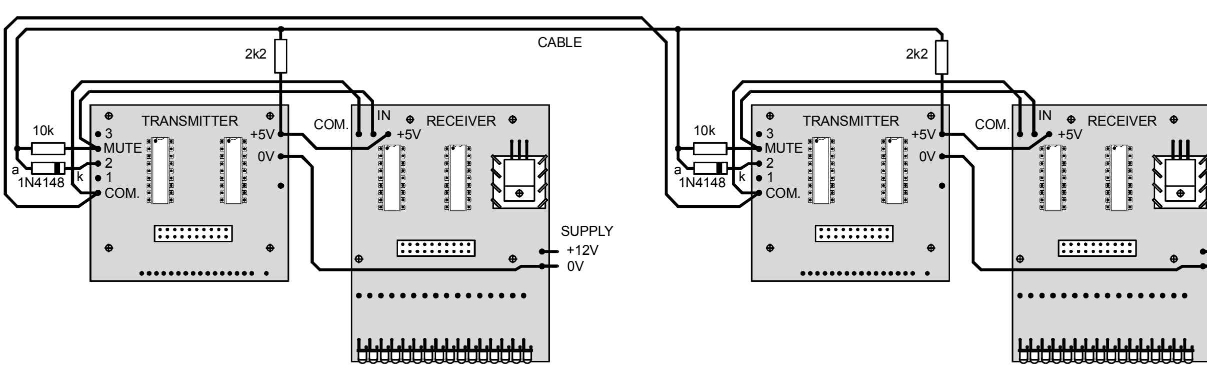


Fig.15. Interwiring to two-way system, without Interface modules.

are used is the generation of radio frequency interference (RFI).

PIC outputs change state in only a few nanoseconds and even a short length of wire attached to one sometimes radiates interference to a VHF radio operating nearby. Connecting them to many meters of cable in a built-up area might prove somewhat anti-social, to say the least! Screened cable could be used, but where this is impractical interface boards can be used to resolve the problem.

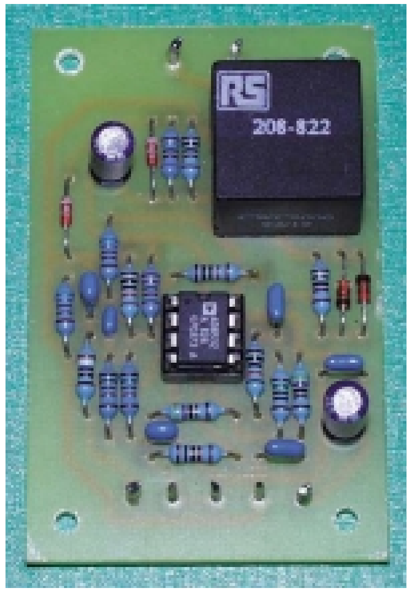
INTERFACE CIRCUIT

The circuit diagram of an Interface Module is shown in Fig.16. Like the Transmitter it is supplied with 5V taken from the Receiver. Local supply decoupling is provided by the capacitors C1 and C2.

The signal to be transmitted is taken from Output 3 of the Transmitter Module, to which optional resistors R3 and R4 (last month) should have been be fitted. This generates the waveform described last month which has a quiescent state of half the supply voltage and a "pulse" consisting of a low state followed by a high one.

Opamp IC1a and associated components form a 3rd order low-pass filter with a cut-off frequency of about 1kHz. The design of this filter allows for the 500 ohm output impedance of the Transmitter.

The filter output at IC1a pin 1, almost sinusoidal in form, is taken from capacitor C6 and coupled to the line through a 600 ohm 1:1 line-matching transformer T1. It is attenuated to the desired level by resistors R9, R10, the transformer and, of course, the impedance of the line, which is nominally the 600



Completed interface circuit board.

ohms of the Interface board at the other end. Zener diodes D1 and D2 protect the circuit from any spikes or transients arising from the line.

The received signal is taken from transformer T1 to the input of opamp IC1b. Resistors R12, R13 and R14 ensure that the DC voltages applied to the inputs of IC1b are around half the supply with the non-inverting input (pin 5) about 80mV higher than the inverting (pin 6) one.

The signal from the transformer is superimposed onto this through capacitor C7, so the output of IC1b at pin 7 is normally high, but every time the input signal goes below 80mV it goes low. This is fed to the Receiver (Rx) through resistor R16 with a second connection (Tx) that is used by the local Transmitter for sensing and muting. Diodes D3 and D4 protect this part of the circuit from line transients.

INTERFACE CONSTRUCTION

The component layout of the Interface printed circuit board is shown in Fig.17. This board is available from the *EPE Online*

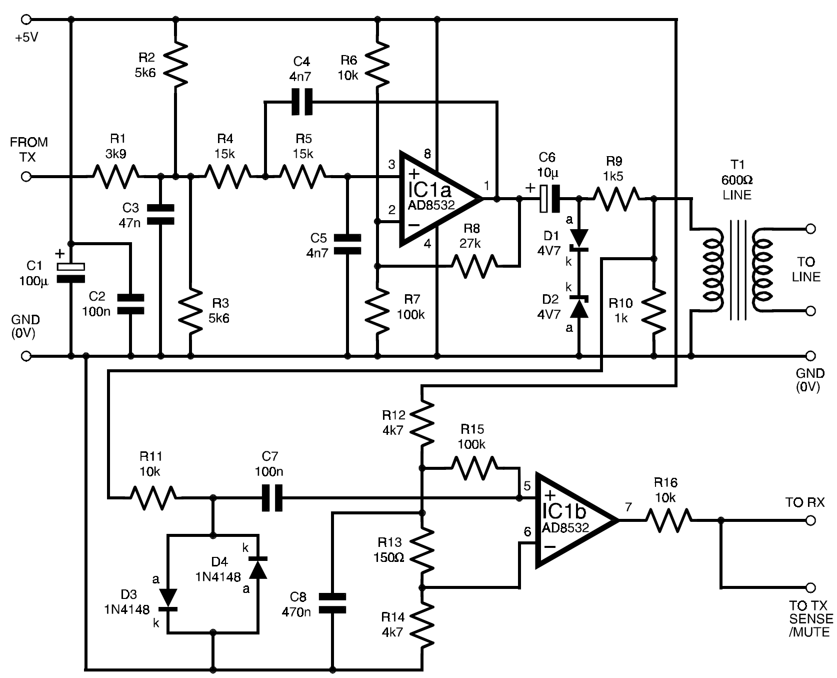
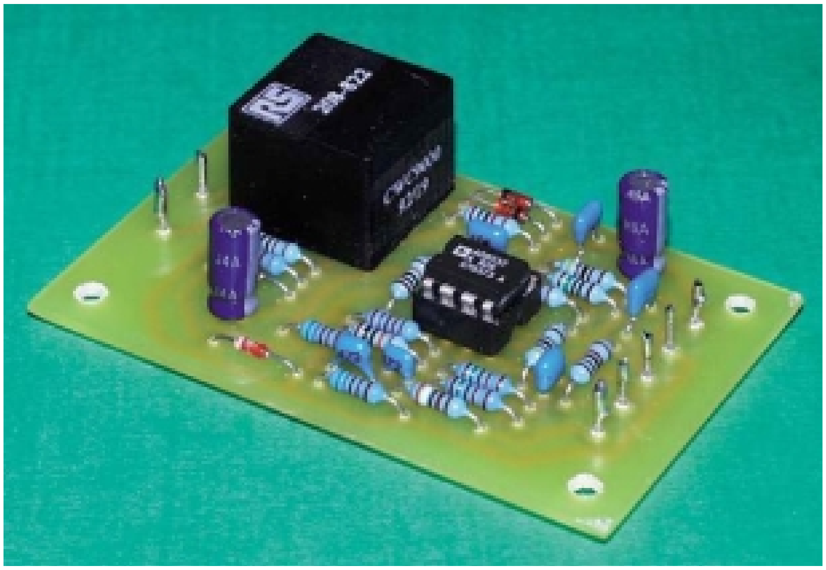
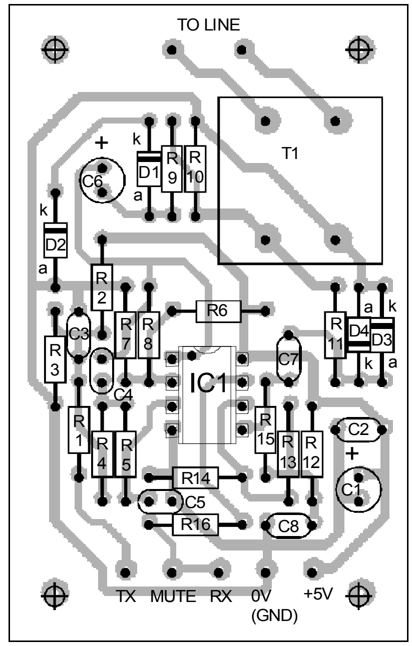


Fig.16. Complete circuit diagram for the Interface Module.



Layout of components on the Interface printed circuit board.



PCB DIMENSIONS: 43mm x 69mm / 1.7in x 2.7in

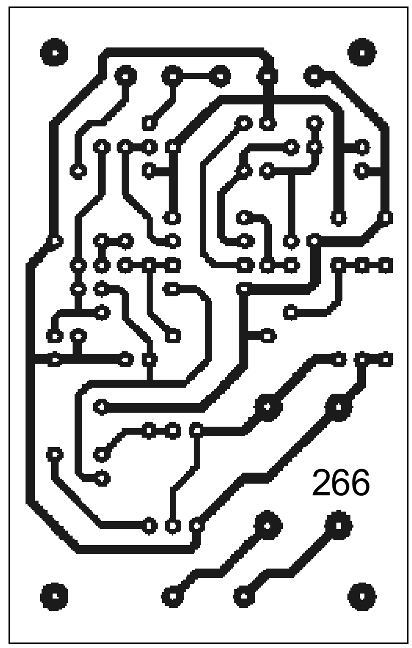


Fig.17. Printed circuit board topside component layout and (approximately) full-sise underside copper foil master pattern for the Interface Module.

Store (code 7000266) at **www.epemag.com**

Construction should prove straightforward. All the components should be fitted in size order, preferably using an 8-pin DIL socket for IC1. The transformer, being the largest component, should be fitted last.

To test the unit it can be connected to a 5V supply which may be obtained from a Receiver Module. The supply current taken should be about 2mA.

Assuming the input is not connected to anything, the output of IC1a (pin 1) should show a voltage of about half the supply or 2·5V and the output of IC1b (pin 7) should be high, at the full 5V since IC1 has "rail-to-rail" outputs. If suitable equipment is available the input may be connected to a Transmitter and the output signals inspected.

The Receiver will deliver negative-going pulses at this stage so long as the "Sense/Mute" connection is not made. A 600 ohm resistor (560 ohms will do) should be connected across the LINE connections if the output signal level is to be checked. The distinctive sound of the output can also be heard if an audio amplifier is connected to it.

TWO-WAY LINK

Two Interface Modules are required for a two-way system. The connections for one end are shown in Fig.18, those for the other being identical. The two wires of the line are simply connected to the interfaces at each end, polarity being unimportant.

With negligible line resistance and both interfaces connected the measured signal on the line should be around 500mV peak-to-peak. If the line has some impedance the outgoing signal level at each end will be greater whilst the incoming signal level will be less, so if alternate bursts of signal having different levels are observed this will be the cause. The system has been tested successfully with lines having a total resistance of up to 850 ohms, although for reliability 200 ohms to 300 ohms should be the maximum.

Internal private telephone circuits often have an energizing voltage applied to them, typically 50V DC. In the case of the

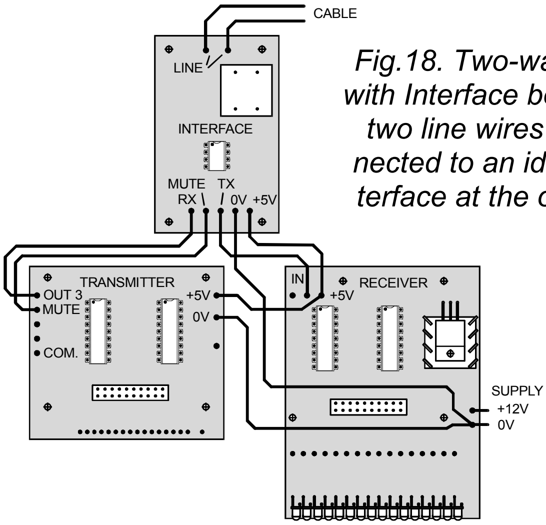


Fig.18. Two-way system with Interface boards. The two line wires are connected to an identical Interface at the other end.

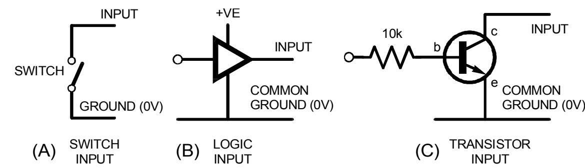


Fig.19. Methods of interfacing inputs to the Transmitter.

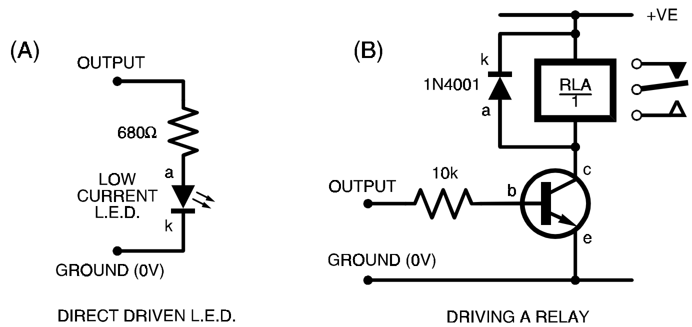


Fig.20. Using the Receiver outputs to drive (a) a LED and (b) a relay.

COMPONENTS

Resistors
R1 3k9
R2, R3 5k6 (2 off)
R4, R5 15k (2 off)
R6, R11, R16 10k (3 off)
R7, R15 100k (2 off)
R8 27k
R9 1k5
R10 1k
R12, R14 4k7 (2 off)
R13 150 ohms
All 0.6W 1% metal film

Capacitors
C1 100u radial electrolytic, 10V
C2, C7 100n resin-dipped ceramic (2 off)
C3 47n resin-dipped ceramic
C4, C5 4n7 resin-dipped ceramic (2 off)
C6 10u radial electrolytic, 63V
C8 470n resin-dipped ceramic

Semiconductors
D1, D2 4V7 Zener diodes (2 off)
D3, D4 1N4148 signal diodes (2 off)
IC1 AD8532 CMOS dual opamp

Miscellaneous
T1 600 ohm 1:1 line matching transformer

Printed circuit board available from the *EPE Online Store*, code 7000266 (**www.epemag.com**); 8-pin DIL socket; connecting wire, solder pins, solder, etc.

See also the SHOP TALK Page!

Approx. Cost Guidance Only **$30**

Hospital where the prototype is used, this could be removed but they prefer to leave it connected simply to indicate to telephone engineers looking for spare circuits that it is in use!

To avoid frying the coupling transformers a 2·2uF 250V polyester capacitor is placed in series with one side of the line connection at each end. Users of similar circuits may wish to do likewise.

INPUTS

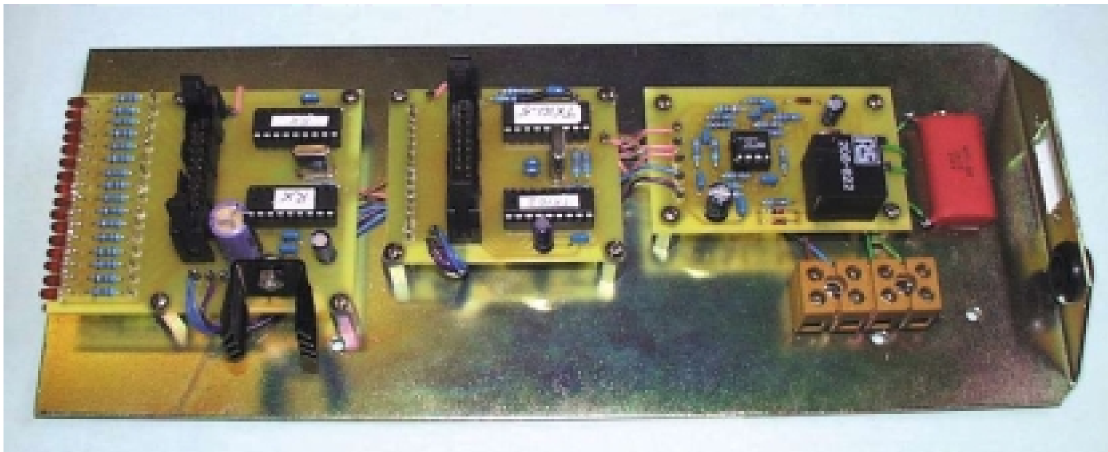
Finally, ways of interfacing the inputs and outputs to other circuits will be needed. Some methods of connecting to the Transmitter are shown in Fig.19. The simplest input connection is just an s.p.s.t. switch that takes an input to ground (negative). This could be an on-off switch, a momentary action type such as a pushbutton, or it could be a microswitch, a reed switch or a pair of relay contacts, depending on the user's requirements.

Alternatively, a logic circuit output could be connected directly to the module provided it is operating from a 5V supply. For greater versatility a transistor can be used. This will allow control by a positive input signal with a much broader voltage range, which may be useful in some situations.

OUTPUTS

Moving on to the Receiver, the LEDs on the board may be all the indication that is required. Alternatively, the outputs may be used to drive another circuit. They go high when active, to 5V, and could drive external LEDs directly though it would be preferable to use low current types for this especially if several are to be used. Current limiting resistors would be required, as shown in Fig.20.

Another option is to use the outputs to operate transistors or MOSFETS, which in turn could operate relays, sounders, more powerful LEDs, lamps or any other device required by the application. They could also be connected directly to logic circuits operating from 5V supplies.



The author's "card" set-up as provided to his local Hospital. The line-up consists, left to right, of a Receiver, Transmitter and Interface Modules. Note the Receiver and Transmitter PIC chips and the finned heatsink on the Receiver voltage regulator IC. The series line capacitor (see text) can be seen top right.

The uses for this project are limited only by the ingenuity of the constructor. Everything from extra inputs for simple security projects to communications, signaling and control of complex systems over long distances can be handled, and the modules may be tailored to provide only the degree of sophistication required for minimum cost.

Note: The listing for capacitor C6 was missed out of last month's Receiver Components list. This is a 100n resin-dipped ceramic type.

InterFACE

ROBERT PENFOLD

Power from the serial or parallel port

From time to time readers query how some readymade serial and parallel port devices manage without a power source. It has to be remembered here, that PC parallel and serial ports do not include any power supply outputs.

In some cases the device concerned is something quite basic that uses light emitting diodes (LEDs) and low power reed relays that can be driven direct from the port's outputs. In other cases the add-on provides a function such as analogue-to-digital or digital-to-analogue conversion, and clearly power is required from somewhere.

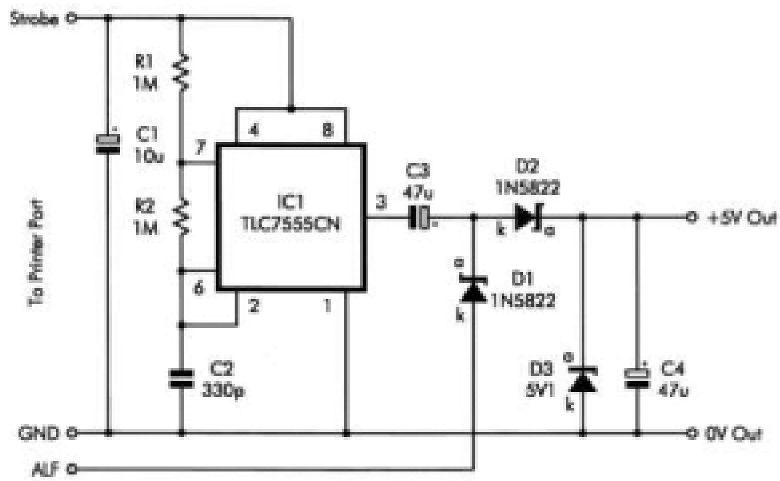


Fig.2. Producing a +5V output from a single handshake output.

PSYCHIC EXPERIENCE

A few years back I had a so-called "out of computer" experience which illustrates how power can seemingly be conjured out of nowhere. An analog-to-digital converter was being tested, and seemed to have a lower full-scale voltage than was expected. The supply voltage set the full-scale value, so the supply potential was duly tested. It was then that I noticed that the power supply for the project was not actually switched on!

Measuring the supply voltage produced a reading of about 3·55V, which was more than the minimum of 3V required by the converter chip. A little investigation showed that the supply was in fact being provided by an unused output of the computer's parallel port that had accidentally become connected to the converter's +5V rail, and not by psychic energy.

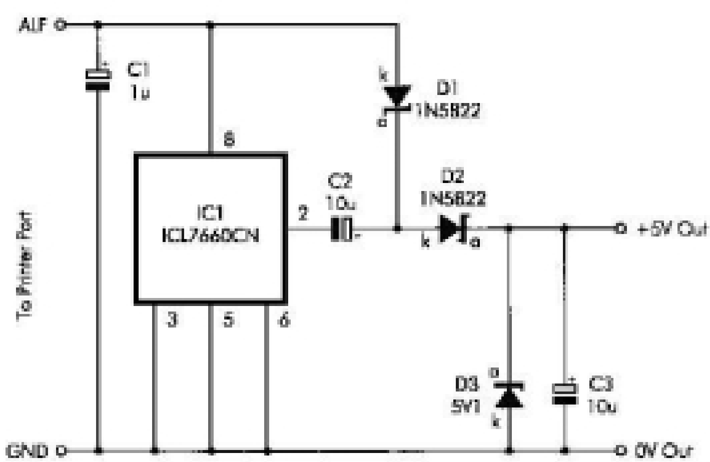


Fig.1. Using two handshake outputs to produce a +5V supply.

MINIMALISM

It may seem like "pulling yourself up by your bootlaces", but some projects can actually be powered from one or more output lines of a parallel or serial port. Any lines used to supply power are not available for other purposes, but there are often one or two spare outputs available.

As one would probably ex-

pect, the power levels available are quite low. Tests on some parallel port outputs showed an unloaded potential of about 4·4V, falling to 3·2V with a 1k (kilohms) load resistance. This equates to an output current of 3·2mA.

Clearly many projects cannot be operated from such a power source, but some interface chips can operate down to 3V or even less, and require low supply currents. Simple circuits based on CMOS chips, provided they do not operate at high frequencies, also have low current requirements and can operate at supply potentials as low as 3V.

With some interface circuits it is the supply voltage rather than the current that is the problem. Many interface chips require something close to a standard 5V logic supply potential, and an unloaded supply potential of 4·4V is inadequate.

HELPING HAND

The circuit diagram of Fig.1 shows one way of obtaining a loaded supply potential of 5V, but two handshake outputs are required. The basic idea is to power an oscillator from one output line, which in this example is the Strobe line. The output from the oscillator is rectified and smoothed to produce a positive DC signal that is added to the voltage from another output, which is the Auto Linefeed (ALF) output in this case.

A set up of this type is potentially less effective than just using the direct output of a single output line. For it to work reasonably well the oscillator must have a very low current consumption, and for this reason IC1 must be a *low power* 555 timer and not a standard NE555.

In fact, some low power 555s work better than others in this circuit, and a TLC7555 gives somewhat better results than a TLC555, presumably due to its lower supply current. The values of timing resistors R1 and R2 have been made high so that the timing circuit consumes a minimal amount of power.

The circuit does not work too well with silicon rectifier diodes used in the D1 and D2 positions due to the relatively high voltage drop through this type of rectifier. Germanium diodes give better results, but for optimum performance Schottky diodes or rectifiers should be used.

With the output unloaded something less than true voltage doubling is obtained and the output voltage is a little under 8V. This drops to about 4·9V when loaded at about 2mA to 2·5mA.

Zener diode D3 should be included if it is important that the output voltage does not exceed more than about 5V. This Zener diode simply loads the output down to a little over 5V even with no load connected.

With the output loaded down to about 5V or less Zener diode D3 does not conduct significantly, and wastes little or none of the output current. Omit D3 if you simply require the highest possible supply voltage, to power a low current operational amplifier perhaps.

INCREASED EFFICIENCY

The circuit diagram of Fig.2 shows a more efficient way of obtaining a 5Vsupply, and this requires only one output line (ALF). It is based on the ICL7660, which is specifically designed for various forms of DC to DC conversion. This device is more expensive than a low power 555 timer, but it offers significantly better efficiency.

This circuit has similarities with the previous one, and it operates in basically the same

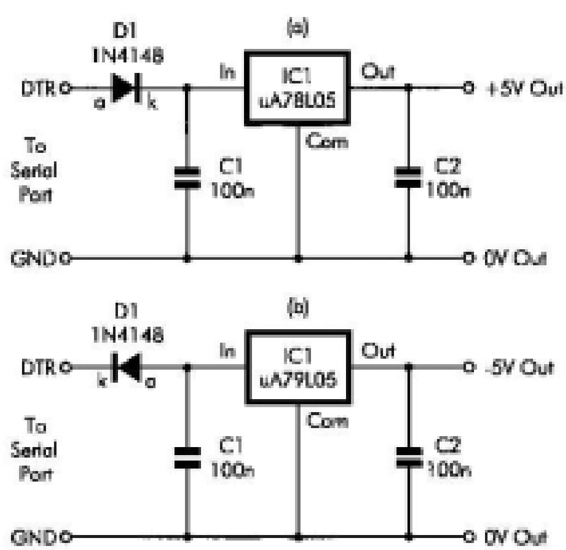


Fig.3. Using the ICL7660CN to produce a negative supply.

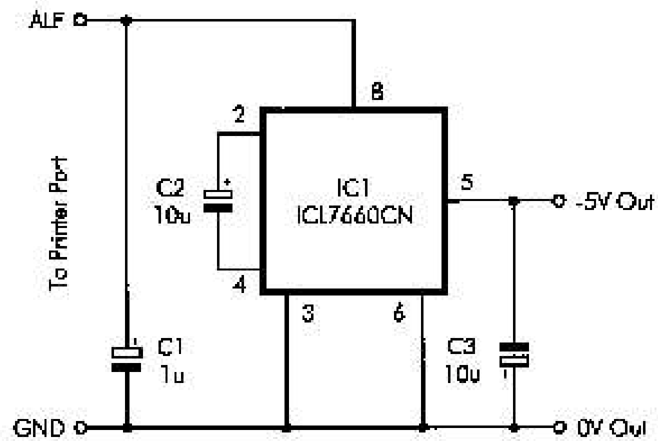


Fig.4. Obtaining a +5V output and (b) obtaining a –5V output from a serial port handshake output.

fashion. When used as a voltage doubler the ICL7660 simply acts as an oscillator that drives an external rectifier and smoothing circuit.

The positive voltage produced by this circuit is added to the supply input to produce a voltage doubling action. The rectifier and smoothing circuit used here is identical to the one used in the circuit of Fig.1.

Although it uses only a single output line as the power source, this circuit actually performs rather better than the circuit of Fig.1. The unloaded output voltage with Zener diode D3 removed is a little over 8V, and an output current of around 3 milliamps is needed in order to load the output down to around 4·9V. This clearly loads the output line quite heavily, but not heavily enough to risk damaging the parallel port's hardware.

NEGATIVE THOUGHTS

The ICL7660 is primarily intended for operation as a *negative* supply generator, and it can generate a negative supply using a parallel port output as the power source. The circuit diagram for a negative supply generator is shown in Fig.3. This circuit does not provide a true –5V output, because the input supply will be less than 5V, and there are losses within the conversion process. With no load there is typically about – 4·25V at the output, which falls to about – 2·9V with a 1k load resistance.

A supply of this type is useful for some analogue-to-digital converters that require a low voltage and low current supply for the input stage. It can also be used with operational amplifiers where a low voltage negative supply in needed in order to permit the output to operate right down to the 0V supply rail potential.

The negative supply generator works on a different principle to that of the voltage doubler circuit, and avoids the need for an external rectifier circuit. IC1 contains a double-pole double-throw (d.p.d.t.) electronic switch that is controlled by the built-in oscillator. This switch repeatedly connects capacitor C2 to the input supply and then to the output, transferring a small charge from the input to the output each time this occurs. Of course, things are arranged so that the output has the necessary negative polarity.

Unlike mechanical switches, their electronic counterparts have significant "on" resistances, and there are some losses from the input to the output. At low currents these are quite small though, and most of the inefficiency of the circuit is caused by the current consumption of the ICL7660 itself.

SERIAL POWER

Tapping off power from a serial interface is somewhat easier than getting power from a parallel type, because the out-

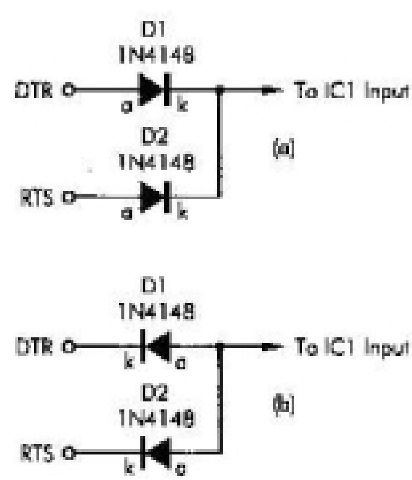


Fig.5. Using two handshake outputs to obtain higher output currents.

puts operate at slightly higher voltages and currents. Also, serial signals use positive and negative voltages, making it easy to produce a supply of either polarity.

Nominal signal voltages are *plus* and *minus* 12V, but the actual unloaded signal voltage can vary a volt or two either side of this figure. The available current is greater than that from a parallel port, but is still not very large. Drawing 10mA reduces the output potential to around 5V.

The transmitter output terminal could be used as a power source, but this will obviously be used for its intended purpose in most serial add-ons. The DTR and RTS handshake lines are more realistic options, since most serial add-ons do not utilize any form of hardware handshaking.

The circuit diagram of Fig.4a shows how a handshake output can be used to provide a regulated +5V supply, and Fig.4b shows the equivalent circuit for a –5V supply. The circuits are essentially the same, but using a positive or negative 5V monolithic voltage regulator (IC1), as appropriate. Diode D1 protects the regulator against an input of the wrong polarity.

Obviously the handshake line must be set to the correct polarity if it does not assume the right polarity by default. In a previous *Interface* article it was mentioned that direct control of the serial port handshake lines seemed to be difficult, but several readers pointed out that it is actually possible. In fact some programming languages such as Delphi have built in facilities to control these lines, so there should be no real problem here.

The maximum current available will vary somewhat from one port to another, but a minimum of around 6mA should be available. For the highest possible output current D1 should be a Schottky diode or rectifier and IC1 should be one of the modern regulators that has a low current consumption and dropout voltage. An output current of up to about 8mA should then be available. Although the circuit is shown as being driven from the DTR line in Fig.4, the RTS line is equally suitable.

TWO HEADS

By using both handshake lines and both circuits it is possible to obtain dual balanced 5V supplies. Alternatively, using a simple diode mixing circuit at the input, as in Fig.5, enables two handshake lines to drive one regulator circuit. Fig.5a is for a positive supply and that of Fig.5b is for a negative supply. When compared to a circuit using a single handshake line, this method enables approximately double the output current to be achieved.

Tapping off power will normally require some additional circuitry, and only limited voltage and current levels will be available. On the other hand, where this method of powering a circuit is possible it offers a neater solution than using a separate power supply or batteries.

However, do not forget that a +5V supply is available from the game port that is present on most PCs, and from the USB ports that are a standard feature on modern PCs. In either case currents of at least an amp are available.

New Technology Updates

IAN POOLE REPORTS THAT THE LATEST FUEL-CELL TECHNOLOGY, USING METHANOL AND SODIUM HYDROXIDE, PROMISES VASTLY IMPROVED PERFORMANCE AS WELL AS BEING ENVIRONMENTALLY FRIENDLY.

Technology is now an ever-increasing part of everyday life and one of the effects of this has been the dramatic rise in the use of portable electronic equipment, laptop computers and mobile phones being just two examples. Traditionally a variety of forms of battery power have been used to drive electronic equipment and, as a result of this growth, battery technology has undergone significant development.

Nickel Cadmium (NiCad) cells have given way to Nickel Hydride (NiMH) ones and many new pieces of equipment are being powered by new technologies like Lithium Ion (Li-ion). These have a much higher power density than both NiCad and NiMH technologies. Yet despite these developments portable power is still a major problem.

FUEL CELLS

One idea that is gaining acceptance is the idea of using fuel cells. These have been known for many years, but until recently their use has been comparatively limited.

It is surprising to find that the idea for them was discovered as early as 1839, but it took until 1950 before the first practical working cells were available. However, it was during the US space program that they first came into their own, and now they provide most of the electrical requirements for the space shuttle.

Essentially, these devices are a form of chemical electrical generator. Energy is supplied to the fuel cell in the form of chemical fuel, and this is converted into electrical energy. Their main advantage is that they have a very high energy density.

Accordingly, their weight and size for the available power is very much higher than that which can be obtained using conventional battery technology. This makes them highly attractive for applications associated with portable electronic equipment where time between charges and the amount of power that can be consumed limit performance and flexibility.

The cells consist of a positive and negative electrode separated by what is known as a proton exchange membrane. The electrodes themselves are coated with platinum and this acts as a catalyst to enable the reaction to take place at a suitable rate.

As the hydrogen, or in some cases a hydrogen rich hydrocarbon, like methanol, is passed into the cells it comes into contact with the negative electrode where it splits into two: electrons and positive ions. In the case of a hydrogen atom the positive ion is a proton, and this gives its name to the separator.

The electrons leave the cell through the negative electrode and the positive ions move across the separator membrane and come into contact with the oxygen molecules. Here they combine along with electrons returning to the cells through the positive electrode.

As long as fuel is supplied to the cell, energy is produced, and unlike primary cells they do not have to be discarded after a short while.

NEW CONCEPT

With the idea of producing a practical form of fuel cell a number of organizations are moving forward their development plans and the results are beginning to hit the news. For example, Motorola recently announced they are developing a fuel cell in conjunction with the Los Almos National Laboratory. Development is in its relatively early stages and unfortunately this means that the cells will not be available in a commercial form for between three and five years.

The cell will be very small and last up to ten times as long as a battery, it will be able to power portable electronic equipment including cellphones, laptop computers and a variety of other equipment. With this capacity it is envisaged that one of these fuel cells could power a cellphone for up to a month.

The prototype cells measure just an inch square and they are less than a tenth of an inch thick, they use methanol as the fuel along with oxygen obtained from the air. The plan is that the cells will use replaceable

methanol filled cartridges. These would be rather similar to ink cartridges used in some fountain pens and the idea is that they would be just as easy to fit.

This will remove the need for bulky battery chargers that are currently required. This is a great advantage because it has been found that business people do not like carrying chargers around.

The other advantage is that the fuel cells with their cartridges are much smaller and lighter than their equivalent battery counterparts. This is a major advantage as anyone who has had to take a lap-top computer around with them will echo.

DEVELOPMENT

Whilst fuel cells offer many advantages they have not been used for consumer applications for a number of reasons. One of their main disadvantages is that they produce a relatively low voltage, and this means that several cells are required in series to produce the required output voltage. When this is done the new fuel and spent products are more difficult to move, requiring fans and pipe-work, making them larger, heavier and less convenient to use.

The new development from Motorola uses a methanol based design that generates 0·8 volts output, although this drops to 0·5V under load. To raise this to the 3V that is usually required a switching regulator is employed. To achieve this, techniques have been used to enable it to operate efficiently from the 0·5V input.

Whilst a large amount of development has been undertaken to improve the performance of the fuel cells themselves, the key to the success of this development is the switching regulator. Currently levels of efficiency between 85 percent and 90 percent are being achieved using discrete circuitry. Ultimately an ASIC will be used, and the circuit will be optimized to give a higher level of efficiency.

ENVIRONMENT FRIENDLY

In the USA a large amount of research into fuel cells has been undertaken. Much of this has been funded by the US government and as a result of this many of the products have only been available in North America. Now many of them are reaching European shores although most are aimed at relatively high power applications.

In one such development a company named Powerball uses plastic coated sodium hydroxide pellets or balls that react with water to produce hydrogen. This reaction is performed in a special tank that regulates the flow of hydrogen to the cell, providing the required amount of fuel. An ingenious method of inserting the ball into the tank removes the outer plastic protective coating, enabling the reaction to take place.

Sodium hydroxide was chosen because of its abundance and low cost. It is a by-product obtained from the production of soap and plastic processing, and it is one of the most widely produced chemicals in the world. Not only is there a good supply, but it is also relatively cheap.

Another advantage is that it is also relatively environmentally friendly as the sodium can be recycled and no harmful carbon dioxide is produced. In fact, such is the interest in this technique that some UK organizations are looking at powering electric vehicles using it.

THE FUTURE

With the large amount of development being invested in fuel cell technology, and their advantages in terms of environmental issues, it is likely that far more will be seen of them in the coming years. Not only will they be used for powering portable electronic equipment, but also as a means of powering electrical equipment and even cars.

By Alan Winstanley

This month's *Net Work* looks at what's happened to CompuServe, and for those who are starting to write their own web pages I offer a simple tip for redirecting users to a new web site.

Back in 1994, we started to think about creating an Internet presence to support *Everyday Practical Electronics* users. At that time there weren't many options available in the UK. Connectivity was slow (9.6 or 14.4kbps), and you needed to be a computer genius to set up a 386 or 486 PC for the Internet, perhaps upgrading the serial port UART in the process. The web and E-mail hardly existed, so only a minority of users actually saw the need for installing an expensive modem anyway. Windows 3.1 did not support Internet networking, so you had to find and install the necessary "winsock" files yourself, or you could persevere and use DOS instead.

DEMONIACAL

UK companies such as CIX and Demon Internet were amongst the very limited choice of services available and along with 20,000 other early adopters I signed up with Demon.

Initially, we actively considered hosting an electronics forum on CompuServe, as this was the most accessible and popular service at the time. Every cover floppy disk boasted "free software", which usually meant the standard CompuServe offering of WinCIM (Windows CompuServe Information Manager) 2.0 or 3.0. This self-installing software was the choice of many Internet PC and Mac users, most of whom belonged to the managerial, professional and technical classes rather than the broad consumer market of today. CompuServe shielded its users from the chaos of the Internet by building a wall around its own proprietary system of E-mail and forums, and only later did it become possible to access external Internet sites more readily. You also needed extra commands to send CompuServe E-mail to Internet users.

Trying to run an alternative ISP alongside CompuServe's software was a challenge. It was very proprietary stuff, and worse, integrating a web browser (CompuServe started out with Spry Mosaic) was not easy, especially if you had already installed a browser of your own (usually Netscape Navigator). Other than that, WinCIM offered the best all-round package and was usually the easiest option for non-technical users to install.

SELF-CONTAINED PROVIDER

CompuServe prides itself on being a completely self-contained Internet Content Provider, which concentrates its resources in a consistent format. Its system of conferences and moderated forums provide information on a very wide variety of topics, including medical, law, publishing, computing and much more. The moderation aspect is a comfort to users who dislike the aggression (or sheer anarchy sometimes) that will be found in, say, a Usenet newsgroup. Extended CompuServe services are available for additional subscriptions.

CompuServe forum administrators (the independents who managed the forum's resources and daily content) received a percentage royalty based on the number of hours that ordinary users accessed that forum. This paid for the administrator's running costs and time.

In my own experience I found that some forum "churn rates'' – how quickly messages were turned over – were almost supersonic, leaving me feeling frustrated and making the forum a waste of time and money. In some forums, messages were deleted in under 24 hours. This meant that you had to access the forum frequently to read any follow-ups, which had the disadvantage of racking up the phone bill (and sometimes your CompuServe bill too). I did have more success in other forums though, but the process was still slow, long-winded and relatively expensive.

In the end we adopted the web and settled on a plain PPP Internet account, and so **epemag.demon.co.uk** was born in 1995. The web and FTP sites followed later. In comparison to using a raw Internet connection – when I could E-mail, use FTP, surf the web, and mail file attachments to my heart's

content – I found that my CompuServe WinCIM began to look increasingly creaky, in spite of the pretty front-end graphics it used to download at intervals onto my machine (at my expense).

COMPUSERVE UPGRADE

A new PC arrived with a later version of WinCIM preinstalled, so I decided to fire it up. Having become accustomed to using my own E-mail client, a separate browser and separate FTP software, I found the CompuServe browser-based software quite strange and not a little bewildering. More recently I tried the very latest CompuServe 2000 package, and found the entire upgrade process fraught with problems. CompuServe 2000 left me cold, and in the event I ditched the idea of the upgrade, and rapidly de-installed it. Then having concluded that I had outgrown the system altogether, I decided to cancel my account.

It took quite some time to find out how to do this. It involved logging in to CompuServe (needing to resurrect my software for this purpose, and using my old-style user ID number, after finding my very old password) and then finding the relevant member’s area. Cancellation involved having to telephone CompuServe, but the Customer Service phone number displayed on the appropriate web page was non-existent.

Eventually I did get through, and the cancellation process involved an attempt by the agent to talk me into switching to the CompuServe 2000 software. I explained that I’d already decided it was far too weird for my tastes. Not one to give up, the agent then offered to switch me to a “pay as you go” tariff, so that my CompuServe web pages would still be alive, and I would just be charged for actual access time. I decided to accept this compromise (well you never know, but don’t hold your breath, I thought).

URL REDIRECTION

CompuServe works well for some users (especially if they travel abroad) but the non-standard front end is not for everyone. I had already anticipated closing my CIS account well in advance by placing a web page on “Our World” which redirects users to my current web site. If you delete a web page, you never know when someone might try to access it in the future. The URL may be bookmarked in someone’s Favorites. Moving a web site needs thinking about, with some advance planning being necessary. You can do yourself a favor by redirecting users to your new page instead, especially if it’s a commercial site. You can do this by putting a META Tag into your “old” page as follows:

```
<HTML>
<HEAD>
<TITLE>Welcome to my old page</TITLE>
<META HTTP-EQUIV=”REFRESH” CONTENT=”2;URL=mynewpage.html”></HEAD>
<BODY BGCOLOR=”#FFFFFF”#000000”>
<!–this is just a redirector page—>
<H3>This page has moved. I’m redirecting you to my new place in two seconds.</H3>
</BODY>
</HTML>
```

The Content=”2;URL=mynewpage.html’’ tag refreshes the browser by redirecting the user to the new URL after two seconds, or whatever delay you prefer.

I finish this month’s column with a challenge – find my old CompuServe home pages and watch it redirect you to my present site! You can contact me by E-mail to **alan@epemag.demon.co.uk**. My home pages are at **homepages.tcp.co.uk/~alanwin**

Technology Timelines PART 5 - CRYSTAL BALLS!

Boldly going behind the beyond, behind which no one has boldly gone behind, beyond, before!

As you will recall, the purpose of this series was to review how we came to be where we are today (technology-wise), and where we look like ending up tomorrow. In Part 1 we cast our gaze into the depths of time to consider the state-of-the-art in electronics, communications, and computing leading up to 11:59pm on the 31st December 1899, as the world was poised to enter the 20th century.

Parts 2, 3, and 4 considered the developments in fundamental electronics, communications, and computing throughout the 20th century. Now, in this concluding episode, we'll buff up our crystal balls and peer myopically into the misty future to ponder what is to come.

MULTIPLE FACETS

In fact there are a number of different facets of future developments that are interesting to consider. On the one hand we have evolution in core technologies and developments in materials science. Next we have trends in products. And last but not least, we have the social consequences to consider.

In the case of materials science, the human race has only just begun to scratch the surface of what is possible. In years to come, today's carbon composite materials will be considered to be our first crude fumblings in this science, comparable to the way in which *we* view the products of the early bronze age! As we gain a better understanding of how things work at the atomic and molecular levels, coupled with an increasing ability to manipulate these structures on an industrial scale, we truly will go behind the beyond, behind which no man has boldly gone behind, beyond, before!

SILICON CHIPS

The core technology driving electronics is of course the integrated circuit (IC), which is commonly referred to as the silicon chip, because most ICs are based on silicon. There are other semiconducting materials available, such as Gallium Arsenide (GaAs) which can be used to create transistors that switch approximately eight times faster and use only a tenth of the power of their silicon counterparts. However, in addition to being highly toxic, GaAs is fragile, difficult to manufacture, and difficult to work with.

Ever since the integrated circuit was invented, manufacturers have been gradually improving their processes and shrinking the size of the transistors, because smaller transistors switch faster and use less power. During the 1980s, transistor geometries shrank from 3·0um to 2·0um and below, eventually reaching 1·0um as we turned the corner into 1990 (where "um" stands for "micron", meaning a millionth of a meter). Today, 10 years later, manufacturers are working with structures of 0·18um, and the shrinking continues.

NAUGHTY PARASITICS

The interconnections (wires) on silicon chips have traditionally been formed from aluminum, even though this metal is not a particularly good conductor of electricity. IC manufacturers would have preferred to use copper, which is one of the best conductors available for most purposes. But copper has a nasty habit of diffusing into silicon, thereby rendering the entire chip useless. So engineers persisted with aluminum, but as structures on the chips get smaller (including the width of the wires) and clock frequencies get faster, dealing with the parasitic track resistance (which slows signal transitions and burns power) becomes increasingly significant.

Towards the end of the 20th Century (it seems so strange to

say that, but there we are), IBM solved the problem of depositing copper tracks on ICs without the copper leaching into the chip itself. Using copper provides a huge speed boost to the chips, and other manufacturers are now starting to license this technology from IBM.

HOMO OR HETERO JUNCTIONS?

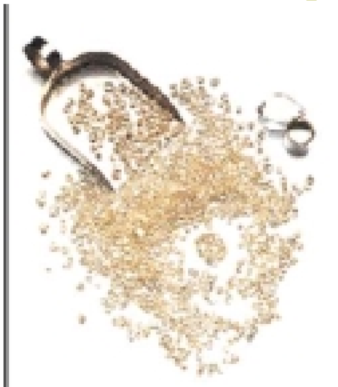
The interface between two regions of semiconductor having the same base element but opposing types of *p-n* doping is called a homojunction. By comparison, the interface between two regions of dissimilar semiconductor materials is called a heterojunction. The interface of a heterojunction has naturally occurring electric fields that can be used to accelerate electrons, so transistors created using heterojunctions can switch much faster than their homojunction counterparts of the same size.

Homojunctions dominate current IC processors because they are easier to fabricate, but the constant drive for more speed is causing a number of manufacturers to experiment with heterojunction devices.

DIAMONDS ARE FOREVER

Diamond is famous as being the hardest substance known, but it also has a number of other interesting properties. For example, diamond is a better conductor of heat at room temperature than any other material (it can conduct five times more heat than copper). In its pure form diamond is a good insulator, and it's also one of the most optically transparent materials available.

But what makes diamond



Diamonds might revolutionize electronics in the future.
(Courtesy H. Goldie Diamond Brokers.)

really interesting to us is that it falls in the same family of elements as silicon and germanium. This means that it has four free electrons in its outermost energy level, which makes it a 4-valence semiconductor, which means we can use it to create transistors. The point is that devices based on diamond are far superior to their silicon cousins. In addition to being significantly stronger

The Dell Latitude. Laptop computers can now run at 700MHz and contain 36GB hard drives. Compare this with the 1960s equipment shown below.

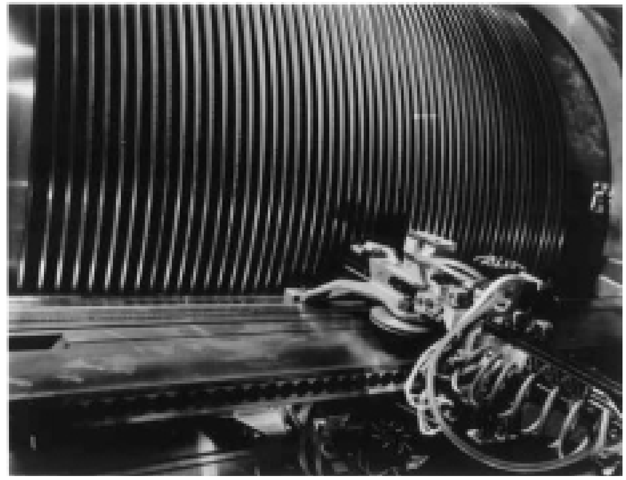
and having the ability to conduct more heat, diamond-based transistors can switch much, much faster than silicon and can function at temperatures of several hundred degrees.

There's only one catch, which is that transistors can only be formed on single-crystal diamond, and the only source of these structures is in naturally occurring diamonds. Now you may think that diamond is too rare and expensive to use for ICs, but in fact DeBeers and the Russians have huge warehouses packed to the gills with the little rascals – they keep them locked up so as to maintain an artificially high price.

The real problem is that, to be cost effective, current IC manufacturing processes are geared to working with semiconductor wafers approximately 25cm (10 inches) in diameter. There aren't too many naturally occurring diamonds like that lying around (and if one were found you can bet that those who stride the corridors of power and don the undergarments of authority wouldn't let us make ICs out of it).

In fact we currently have the technology to create diamond films using microwaves to heat mixtures of hydrogen and hydrocarbons into a plasma, out of which the films can be deposited on suitable substrates (base layers). However, the resulting films have structures that are formed from billions of tiny crystals instead of from one big one. Thus, scientists and engineers are working furiously to create a substrate material that will promote the growth of single-crystal diamond films. This could happen today, next month, or ten years from now, but whenever it comes to pass it

A typical 1960s computer installation. This is the IBM System/360. (Courtesy IBM Archives.)



An IBM RAMAC disk storage system from the '60s. Each disk is about 300mm (12 inches) in diameter. (Courtesy IBM Archives.)

will revolutionize electronics as we know it!

A STACK OF CHIPS

Electronics designers are constantly trying to squeeze as many transistors as they can into the smallest space possible. One interesting idea is based on the fact that the slivers of semiconductor used to form ICs are only approximately 0·2mm thick (and most of this thickness is only required for mechanical strength, because the transistors are formed to a depth of only a few microns on the surface layer).

Thus, assuming chips that are 10mm square and 0·2mm thick, it would be possible to build a 10mm cube composed of 50 chips stacked on top of one another. But there's a problem with this chip-on-chip (COC) technique – heat dissipation! A single high-end microprocessor chip (like a Pentium III, for example) can dissipate approximately 40 watts, and this increases as the clock frequency goes up. It's hard enough to dissipate this amount of heat, so we can only imagine the problems associated with 50 of the little rapscallions in a 1cm cube.

Even if we could solve the heat dissipation problem, there's the problem of connecting the chips together. If the chips were based on silicon, the techniques for connecting the slices forming the chip stack are relatively limited (the most likely being running vertical wires up and down the sides of the cube).

But wait! As you may recall, diamond is one of the most optically transparent materials available. Suppose that the chips were made from diamond, which in addition to being able to withstand extremely high temperatures is also the best conductor of heat on the planet. It's also the most optically transparent substance available, and we know how to construct laser diodes and phototransistors. So it would be theoretically possible to create something with the computing power of 50 Pentium III processors in a 1cm cube, where the layer-to-layer communication was performed using optical signals.

Pretty cool eh? And the really cool thing is that although this is difficult, it's well within the realms of possibility in the foreseeable future (if you've got good glasses).

BLINDED BY THE LIGHT

The hard disks used to store data in computers have made tremendous progress in recent years. It may be difficult for younger readers to comprehend the fact that hard disks used to be a tad bigger and held somewhat less data than they do today.

For example, one system built by the Librascope Corporation in the late 1960s (little more than 30 years ago!) used disks that were four feet in diameter and could store less than 1MB of data! You wouldn't believe the thermal tracking problems associated with these devices, and most of the disks actually ended up serving a role for which they were far-better suited – as coffee tables!

But time marches on, and

today's hard disks are a triumph of engineering. In fact you can now purchase a disk that holds more than 36 GB that's only about 100mm (4-inches) square and 25mm (1-inch) thick. All of which is pretty amazing and jolly good, but at the end of the day we're still talking about coating a disk with magnetic material and spinning it round at 10,000 RPM. Is it just us, or do hard disks lack the luster we always associated with "Buck Rogers in the 21st Century" (be fair, we had to squeeze him in somewhere).

As it happens, there's a lot of development going on in optical storage. It's believed that as much as one terabyte (1000 GB) could be stored in a 1cm cube using today's technologies … if only we had the right cube. There have been some notable successes based on creating cubes of bi-frequency photosynthetic proteins suspended in transparent polymers. Unfortunately the materials used thus far tend to forget their data after a few weeks, which is less than ideal when you're talking about long-term computer storage.

But once again we're back to materials science. We *will* discover suitable materials – it's only a matter of time – and when we do…

COLD ENOUGH TO...

And then there are superconductors, which are conductors with zero resistance that have a tremendous range of potential applications. We say "potential", because even though superconductors are in use today, they require extremely cold temperatures to function, which makes them less than optimal for everyday applications.

Way back in 1911, the Dutch physicist Heike Kamerlingh Onnes discovered superconductivity manifesting itself in mercury cooled to 4K (4 degrees Kelvin, which is equivalent –269°C, and which is only 4 degrees above absolute zero – the coldest you can get). Initially it was thought that superconductivity was caused by the atoms in the material not moving due to the extremely low temperatures. However, materials that exhibited superconductivity at higher temperatures were subsequently discovered.

By the early 1990s a family of materials based on copper oxide and mercury attained superconductivity at 160K (–113°C), which starts to become very interesting. The search is currently on for so-called "room temperature" superconductors, which will revolutionize electronics as we know it if (when) they are discovered. (Note that we're in the realm of materials science once again.)

As an aside, there are many theories as to how superconductivity works, some of which are so complex that they are only understood by very few people on the planet. But, truth-to-tell, no one really understands it one hundred percent (much like magnetism – although we know what it does we don't fully understand what causes it at the most fundamental levels).

Now if the authors were experts on conductivity, this is the point where they might be tempted to start muttering under their breaths about such esoteric concepts as *"Correlated electron movements in conducting planes separated by insulating layers of mesoscopic thickness, under which conditions the wave properties of electrons assert themselves and electrons adopt the properties of waves rather than particles."* But they aren't, so they won't!

TRANSMOGRIFICATION

If we were to take a "30,000 foot" view of electronics, we might say that we start off by thinking of something we want to do, then we come up with an algorithm that describes how we want to do it. The next step is to map this algorithm into some sort of physical implementation that will actually perform the task.

For example, let's assume that we want to create a codec (CODer-DECoder – a circuit that converts audio or video signals into digital code, and vice versa). Once we've worked out the algorithm we want to use, we could decide to implement it out of "jelly-bean" ICs (simple off-the-shelf functions), but the result would be relatively large, heavy, and unwieldy. So if we wanted to use our codec in say a cell phone, this approach would be a non-starter.

Another technique would be to create an application-specific integrated circuit (ASIC). These devices, which can contain millions of transistors, are expensive to develop, but the cost-per-unit falls to a few dollars if you make enough of them.

Although an ASIC will offer the most efficient implementation possible, there are two major problems with this approach. First of all, each major function in the cell phone (like our codec) will require its own set of transistors, or perhaps even its own ASIC. Secondly, codec (and cell phone) standards are changing

so fast that by the time the ASIC is produced it is already obsolete.

Yet another technique is to use a general-purpose microprocessor or a digital signal processor (DSP), which is a specialized form of microprocessor. In this case the algorithm would be implemented as a software program. This approach has the advantage that the algorithm can be quickly and easily "tweaked" and modified. But the big disadvantage is that this technique offers only a fraction of the efficiency of an ASIC in terms of processing speed.

So we seem to be between a rock and a hard place – especially when we consider the explosive growth in cell phones and other handheld devices, which need to be as small and lightweight and consume as little power as possible. One answer to this conundrum is reconfigurable hardware – that is a device whose internal functions can be reconfigured at extremely high speeds "on-the-fly" while the device is resident in the product. This would allow a single device to perform the tasks of multiple hard-wired devices, and also to be easily upgraded to support evolving algorithms.

Available design tools and reconfigurable devices are still in their infancy, but you can expect to see dramatic developments in this area in the very near future.

PRESUMPTUOUS POLYMERS

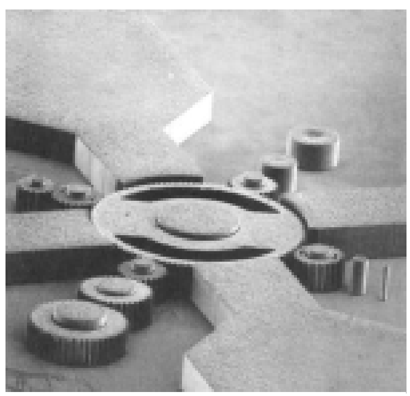
One area of materials science that remains largely unnoticed by the general public is that of plastics technology (so long as your carrier bag doesn't split and drop your groceries on the floor, who cares?).

But in fact research into different polymers is resulting in some incredible developments. For example, in the latter half of the 1990s, some cunning French scientists discovered how to screen-print plastic transistors. Although these aren't suitable for use on integrated circuits, they may well prove to be tremendously interesting for large-screen display devices.

Also, in 1999, reports emerged about research into polymer-based battery technology – that is, batteries formed from thousands of incredibly thin layers of different polymers sandwiched together. One of the biggest (and heaviest) components of a handheld device like a cell phone is the battery – another is the case. But this polymer technology may result in the case being the battery!

ALL IN THE GENES

We're sort of used to programs that do one thing, and keep on doing the same thing



A micromachine gear train magnified 200 times.

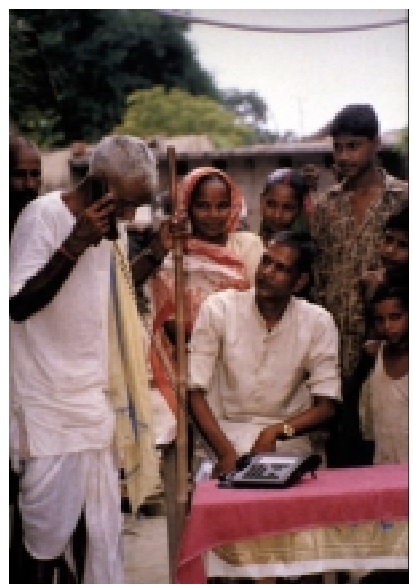
even if we don't use them very often. However, there's a very interesting discipline known as "Genetic Algorithms", which are programs that are crafted to mimic evolutionary processes in the real world. To put this another way, genetic algorithms can mutate and evolve themselves to find the best solution to problems involving large numbers of variables.

Two other areas of interest are those of "fuzzy logic" and "neural networks", and engineers are currently experimenting with different combinations of these disciplines to produce some truly unique offspring.

Of course, the really interesting stuff will begin when reconfigurable logic comes to maturity, at which point combining self-evolving algorithms with dynamically configurable hardware will result in … some truly mind-boggling projects in *EPE* and *EPE Online!* (And don't even get us talking about micro-machines, protein switches, and nanotechnology!)

BEAM ME UP SCOTTIE!

Now it's time to turn our all-seeing gaze in the direction of some key product trends. The



An Inmarsat satellite phone in use in a remote part of India. (Courtesy Inmarsat.)

SCOTTIE MARK II

In addition to their cell phones, many people have started to carry personal digital assistants (PDAs) – such as a Palm Pilot – which they use for tasks like scheduling appointments and storing the contact details of their friends and business associates.

Some people also carry a digital camera that they use to record special events (or anything that moves in some cases) while others favor a mobile global positioning system (GPS) device that they use to locate business addresses (or themselves) on their travels.

The functionality of all of these devices will eventually be merged into a single personal communications device. This unit will be capable of sending and receiving voice and data messages; capturing, displaying, transmitting, and receiving images; determining one's position anywhere in the world; translating to and from the local language wherever one happens to find oneself (and also telling the time) – all from a single device the size of a small cell phone.

The user interface (UI) model for these devices will also undergo a transition, from today's keypad mode of operation to true handwriting and speech recognition in the not-so-distant future.

ELECTRONIC PUBLISHING

Publishing today is dominated by the print media. The invention of the radio and later the television were both heralded as the beginning of the end for the printed word, yet newspapers and books have endured throughout the ages. There is something about holding and reading a paper book that satisfies the user in a very fundamental way. Having said this, print media will not long remain the primary vehicle for information dissemination and delivery.

Early attempts at producing electronic books (e-books) have been less than successful for a number of reasons, not the least being the cost of an e-book system ($500 to $750 US dollars as of December 1999). Another consideration is the poor resolution and quality of e-book text due to the display technology of the day. There's also the aesthetic and tactile look-and-feel of a good book, which is far superior in most user's minds to that of a plastic e-book device.

However, the technological problems will be solved in time. Higher resolution display devices will become available, companies such as Microsoft are developing new font technologies that will make electronic text much easier to read, and the cost of these devices will inevitably fall through the floor.

Some of the driving factors for end-users will be the instant availability of huge amounts of information at their fingertips, coupled with the ability to access audio, visual, and multimedia content. In fact electronic books have many advantages for both end-users and publishers. The cost of publishing an electronic book is greatly reduced, because the publisher doesn't have to produce a master plate for each page, or pay a printer to print a minimum order of thousands of copies of the book, or pay a distributor to move the books to retail stores. Also e-books are intrinsically environmentally friendly (you don't have to kill a forest to print an e-book).

Readers of *EPE Online* (**www.epemag.com**) – the web-delivered version of *EPE* – are themselves helping to pioneer this technology of the future, and along the way they are receiving the advantage of the reduced cost of distribution. The cost difference for a 12-month subscription between the online version ($9.99) and the printed version ($50) is a reflection of the technology used to produce and deliver the magazine, and ends up as a direct saving that can be passed on to the end user.

CONTENT CREATION

Retail stores, the publishing industry, and digital media are segmented markets today, but they are beginning to merge. For example, consider large American department stores, who historically produced and distributed ferocious quantities of printed catalogs. These stores are now furiously investing in in-house television studios so that they can create their own video content. At the same time they are investing heavily in e-commerce solutions and web-based content creation technology.

Why are high street "names" like Sears investing in this technology? Well for a start, they've seen catalog-based companies like Landsend (**www.landsend.com**) transferring their business to the web, carving out new markets, and making humongous profits on the way. Retail space and staff costs are increasingly expensive, so web-based e-commerce sites that can deliver real-time interactive walk-throughs of virtual shopping

The Siemens IC35 unifier provides Web access, email and fax, it also includes a smart-card slot for future banking.

The Nokia 7110 provides internet access together with "Naviv Roller" predictive text input.

malls that exist only in cyberspace offer a very attractive alternative.

This new approach provides many advantages. For example, a UK-based clothing store now has the opportunity to market its goods to a world-wide audience. People can shop from the comfort of their own front rooms, using web-enabled applications that provide an enjoyable shopping experience without getting trampled in the stampede for a bargain! Meanwhile, the "store" gains additional margins from the reduced costs associated with not having to maintain large and costly high street properties.

The race has started to own the technology that will enable true virtual stores. Companies that either generate 3D content or offer 3D visualization software are being acquired by other companies that specialize in e-commerce solutions. Content is perceived as being the key to the success of the next generation of online stores. Virtual stores where people can enter and "walk around" a three-dimensional world looking and touching virtual goods on virtual shelves is not that far away.

In addition to huge virtual book stores like Amazon (**www.amazon.com**), other areas in the commercial arena that have already entered into the world of virtual business are banks and insurance companies, who are becoming increasingly attractive as they pass the benefits of reduced costs onto their customers.

"Everything that goes around comes around," as they say. The large superstores chased the small specialized shops off the high street due to the price pressure they were able to apply due to their bulk-purchasing power. In response, many of these small businesses turned to the web and started to carve out some very successful niches. In many ways this has been a powerful factor in forcing the larger stores to respond in kind.

DISTANCE LEARNING

Distance learning was pioneered in Australia where, for many years, children in remote locations have received tuition via shortwave radio and television programs. Over time, distance learning programs appeared all over the world, but progress has been relatively slow in many countries due to the lack of a suitable infrastructure. However, the advent of the web has proved to be a tremendous accelerator to distance learning, which is now poised for exponential growth.

No longer will access to higher education be limited to the lucky few who can afford access to the limited number of Colleges and Universities. Students around the world are already able to access streaming audio and video presentations, and will soon be able to interact with lecturers and each other across the globe in real-time.

HOLD ON,

HERE WE GO!

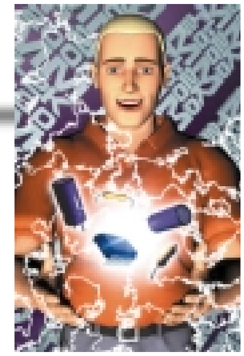
As we said when we began this series, only one hundred years ago an incandescent light bulb could cause a crowd to gasp in awe, and the most complicated calculations were performed using only pencil and paper. As little as eighty years ago, listening to a rudimentary radio was the privilege of the favored few. Just sixty years ago, only a tiny minority of the population had any access to a telephone.

Similarly, color television was well beyond the means of most households when it was introduced a little over 40 years ago. The thought of personal computers in the home was inconceivable to the vast majority of the population as little as 20 years ago. And no one had even heard the term "world wide web" ONLY SEVEN YEARS AGO!!!

What can we say? We've only touched the surface of what is to be. Truth to tell, it's almost impossible to predict any sort of development for more than a few years ahead.

All we can say for certain (and you can quote us on this) is that the future will be far stranger than we can conceive, it's coming much faster than we think, and the social impact will be phenomenal! Captain James T Kirk didn't have a clue!

TEACH-IN 2000



PART PART 8 – Comparators, Mixers, Audio and Sensir Amplifiers by John Becker

Over the first six parts of Teach-In 2000, which we know you have been greatly enjoying, we covered passive components and several digital logic circuits. Via the interactive computer programs and the simple interface you assembled, you have also been able to observe the various waveforms generated by the experimental breadboard circuits, showing how a few electronic components can be connected to achieve interesting results.

Last month we moved on from the "interesting" to the "practical", in terms of describing active components which can be used to amplify and otherwise modify the waveforms generated. We began to examine opamps – those simple robust components that feature so frequently in audio and other analogue circuits, and we demonstrated their basic nature. This month we get you experimenting with some useful applications.

COMPARATORS

THE subject of *comparators* almost brings us back full circle to when we were explaining how digital circuits such as inverters and gates respond to changing voltage levels on their inputs, their outputs changing state when the input voltage crosses predetermined thresholds. In those circuits, the threshold levels are a product of the device's design. In other words, it is fixed during manufacture.

An opamp can also be used so that its output changes between fully high and fully low in respect of given voltage levels on its input. In this type of application, in which negative feedback is omitted, the circuit is said to be configured as a *comparator*.

As the term suggests, the opamp *compares* the levels on its inputs and when there is a difference in voltage between them, full amplification is given to that difference and the output swings to the highest or lowest appropriate state – as does a digital gate.

Two major differences exist between a digital gate and an opamp comparator. First, and most significantly, the threshold voltage at which the opamp changes its output state can be preset from within a circuit.

Secondly, but not necessarily of importance, the output voltage level may not fully swing between the power line l evels (a matter we commented on in Part 7).

COMPARATOR DEMO

Using the buffered waveform that is available from IC4b (as described last month), we shall demonstrate adjustable comparator action using IC4a.

Note that in many applications, the comparator can be connected directly to the original signal whose level needs to be compared against another. Indeed we could do so here, connecting the waveform from IC1a pin 1 directly to a comparator stage. However, it is frequently

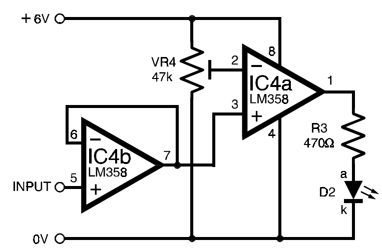


Fig.8.1 Circuit diagram for a buffered non-inverting comparator

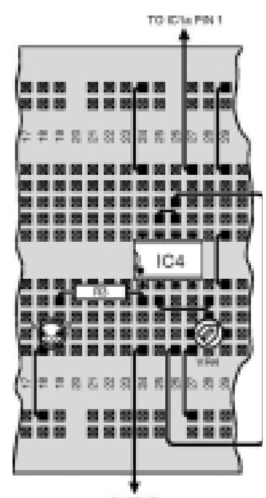


Fig.8.2. Breadboard assembly of the circuit in Fig.8.1.

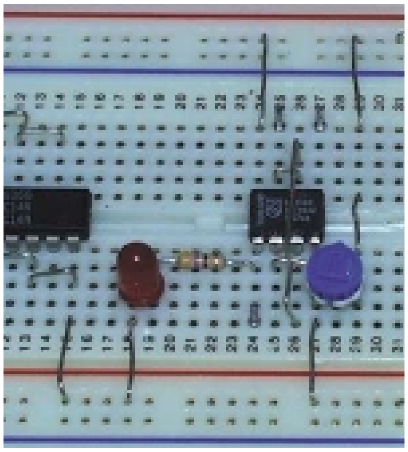


Photo 8.1. Detail of the breadboard layout of Fig.8.2.

preferable to buffer a signal which comes from a circuit whose response could be upset by its connection to another circuit, and so we emphasize the point now by using a buffer.

We'll examine a non-inverting comparator first. The circuit is shown in Fig.8.1 and, to demonstrate the comparator's output state, uses a LED (D2) fed via ballast resistor R3.

Assemble this circuit on the breadboard as shown in Fig.8.2.

TRIGGER THRESHOLD

Preset VR4 sets the comparator's trigger threshold voltage onto the inverting input (pin 2). Set its wiper to a midway position. Note that a feedback resistor is not used in this application. The input signal to be "compared" is connected to the non-inverting input (pin 3).

Set preset VR1 (oscillator) to its midway position, so that a triangular waveform is generated (with oscillator diodes D1 and D2 in place). Use a 100uF capacitor for C1.

With power on and the oscillator running, observe the flashing of LED D2. It should be fairly evenly spaced for on and off. Adjusting the wiper of preset VR4 *fractionally* back and forth about its midway position, you should see that D2's on/off ratio changes. Outside of this fairly narrow range of VR4, the LED should cease flashing completely, remaining either fully on or fully off.

What you are doing when adjusting VR4 is to change the threshold voltage at which the comparator "flips" its output state. With the signal voltage *below* the threshold voltage, the opamp applies full amplification to what it sees as a negative voltage difference (input less than bias), thus the bias on the inverting input has dominance and the opamp output goes *low*, and the LED is turned off. When the signal voltage is *above* the threshold, it has dominance and so the opamp output swings *high*, and the LED is turned on.

INVERTING COMPARATOR

If you swap over the connections to the opamp's two inputs, the situation will be reversed, and the output will go *low* when the signal input is *above* the threshold voltage, and vice-versa.

Experiment with different settings of VR4 and values of oscillator capacitor C1.

Another matter to experiment with is the sensitivity of VR4's wiper position. The physical rotation range can be broadened by inserting resistors to either side of its outer pins, replacing the link wires which at present connect them to the positive and 0V power lines. Two resistors each of 22kΩ would be a good starting point. Such techniques allow bias voltages to be much more accurately set by preset controls.

You can also monitor the output of IC4a (pin 1) via the ADC device and computer, as you have done with previous analogue circuits. Decreasing the value of oscillator capacitor C1 to 22uF, or even 1uF, will allow the pulse widths to be seen more readily.

HYSTERESIS

Way back in the series (Part 2) we discussed a digital inverter's sometimes uncertain response when the input voltage is only slowly crossing the threshold voltage level. We explained that a

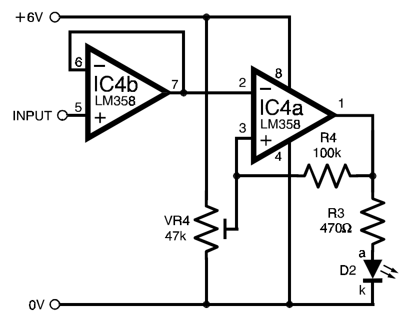


Fig.8.3. Circuit diagram for a buffered inverting comparator with hysteresis.

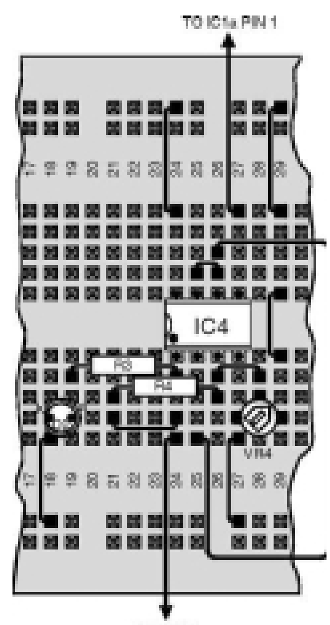


Fig.8.4. Breadboard layout for the circuit in Fig.8.3.

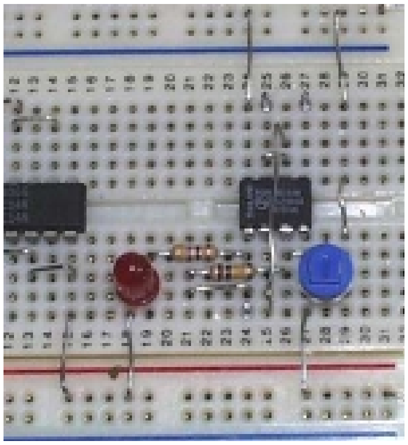


Photo 8.4. Actual breadboard for Fig.8.3 and Fig.8.4

certain amount of "dithering" could occur, resulting in several changes of output level instead of one (Photos 8.2 and 8.3 illustrate a similar situation found in comparators). It was further explained that an inverter having a Schmitt trigger characteristic could be used to avoid this situation, ensuring the output changes always occurred cleanly.

There is no such component actually called a Schmitt trigger opamp (although there are opamps specially designed for use as comparators and which have clean output switching).

However, an ordinary opamp can have its surrounding circuit slightly modified to provide a similar effect. This effect is known as *hysteresis*. It is simply achieved by the addition of one extra resistor, R4, as shown in Fig.8.3. The breadboard layout is shown in Fig.8.4.

Again feedback comes into play, but this time it is made to the *non-inverting* input, and as such reinforces the signal level already there. The term given is *positive feedback*. As with negative feedback, the amount of positive feedback is controllable by the choice of value for the feedback resistor compared to the resistance at the input.

Resistor R4 is one positive feedback component, the resistance offered by VR4 is the other. Here too it is a matter of ratios, but the principal controlling component is usually regarded as the feedback resistor, R4.

HYSTERESIS CALCULATION

In calculating the value for R4, we return to the resistors in series and parallel formulae, discussed in Part 1.

First consider the resistance to either side of the wiper of VR4. Often both sides of this potential divider would be equal, the wiper having been set to provide a midway bias voltage (although this does not need to be the case).

To take the circuit of Fig.8.3 and its values as the example, VR4 has a value of 47k, so the resistances to either side of its wiper are each 22·5kΩ, say 22kΩ. Call the upper resistance Ra and the lower Rb. Because the 6V supply voltage is equally divided by Ra and Rb, the voltage at their junction is 3V.

Assume as a first instance that the output of IC4a is low, at exactly 0V. The potential divider now effectively sees the resistance of R4 (100kΩ) in parallel with Rb. Call this combined resistance value Rc. Using the resistors in parallel formula:

$$Rc = 1/((1/Rb) + (1/R4)) = 9{\cdot}09\text{k}\Omega$$

call it 9k1Ω.

Now using the potential divider formula, the divided voltage becomes:

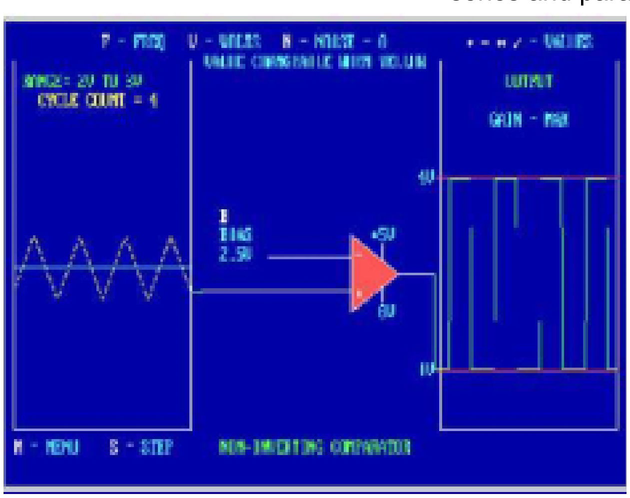


Photo 8.2. Screen dump of the non-inverting comparator demo showing how a simple input waveform causes clean output pulses.

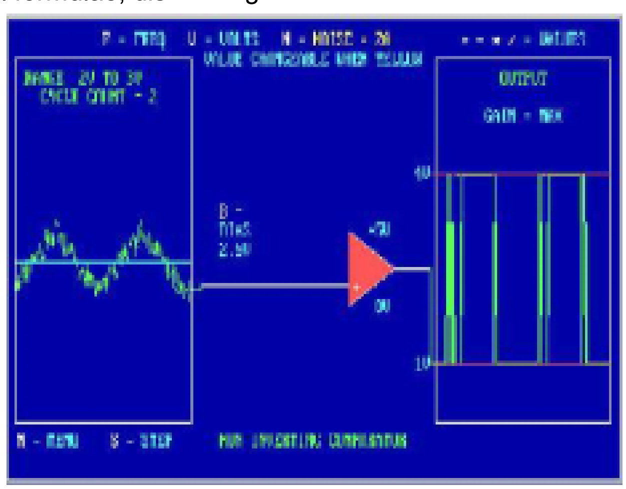


Photo 8.3. Screen dump of the same demo as in photo 8.2 showing how noisy input signals can cause erratic triggering of the output.

6V x (Rc/(Rc + Ra)) = 2·86V

Next consider the situation when the output at IC4a is high, at exactly 6V. It is now Ra that is in parallel with R4. Call the combined resistance value Rd, which in this case is the same as Rc, 9k1Ω. In this situation the divided voltage becomes:

6V x (Rb/(Rd + Rb)) = 3·14V

TRIGGER HAPPY

What this achieves is that two trigger threshold values now exist, 2·86V and 3·14V. The one that applies at any time depends on whether the opamp output is high or low.

When the output is high and the 3·14V threshold applies, the incoming voltage at the inverting input has to rise above 3·14V before it causes the output to change state, down to 0V.

Now the threshold becomes 2·86V, and the incoming voltage has to fall below 2·86V before the output again changes state, back to high, at 6V. And so the cycle will continue.

As with a Schmitt inverter, we have a hysteresis window, in this case from 2·86V to 3·14V, within which no change can take place. No more erratic changing of the output level occurs in response to slowly changing or noisy input voltages. Other window ranges can be set using different resistance values, but still using the same formulae.

Note that where resistances Ra and Rb do not need to be exactly equal (and they probably don't in many comparator circuits), a preset need not be used and Ra and Rb could be chosen as fixed value resistors.

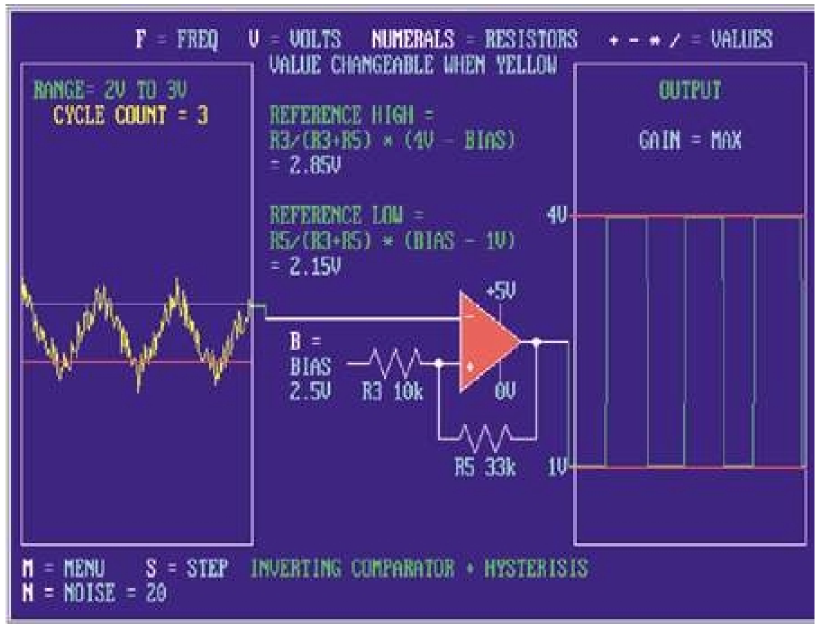


Photo 8.5. Screen dump of demo illustrating how hysteresis allows a comparator to ignore noise on the input signal.

SWING RANGE SNAG

Have you spotted the snag, though, with regard to the opamp we are using here? Its output does not swing between exactly 0V and 6V. As already said in Part 7, the likely range will be less, say 0·5V to 5·5V. How do we cope with this to set up the hysteresis window?

Simple, you proportionately reduce the value of R4 in order to compensate. One way of tackling this is first to calculate R4 as though the opamp output *does* swing fully between 0V and 6V, and then use the potential divider formula to establish what ratio of R4 corresponds with the actual opamp output levels.

As an example, take R4 as 100kΩ again and the actual opamp minimum and maximum output voltages as 0·5V and 5·5V. You still want to achieve a hysteresis window of 2·86V and 3·14V.

Consider R4 to be split into two resistances connected in series (Re and Rf), both values unknown but totaling 100kΩ. Now regard the outer end of Re as being at the lower window value, 2·86V, and the outer end of Rf as being at 0V. The voltage at the junction of Re and Rf represents the opamp's minimum output voltage of 0·5V. Now we ask what ratio must Re have to Rf in order to achieve a potential divider voltage of 0·5V when the total resistance has 2·86V across it.

First divide 0·5 into 2·86 and then divide the answer into the total resistance of Re + Rf, which we have said is 100kΩ. This gives the value for Rf. Re is thus 100k – Rf:

100k/(2·86V/0·5V) = 17·48k
100k – 17·48k = 82·52k

Another way is to first subtract 0·5 from 2·86 = 2·36. Now divide 2·86 by 2·36 (= 1·21186), then divide this answer into 100k (= 82·52k).

The value that R4 must actually have to achieve a lower

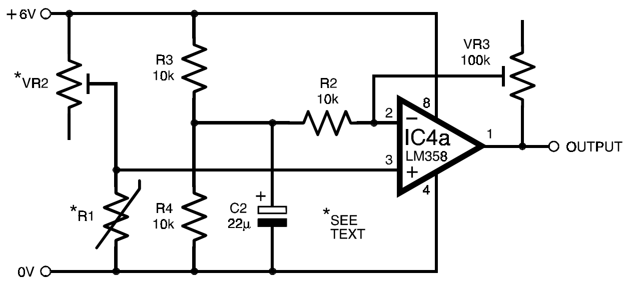
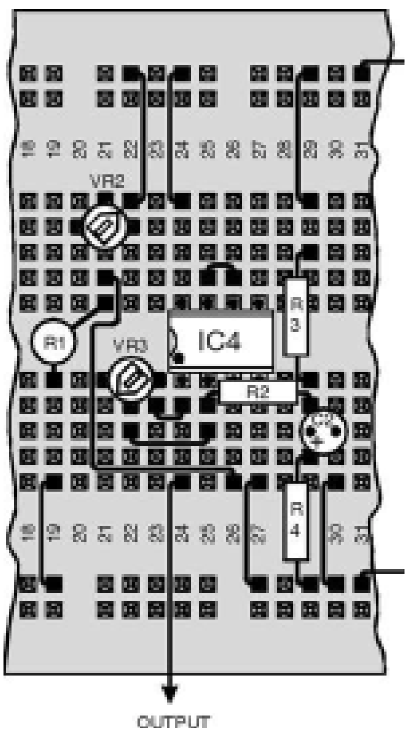


Fig.8.5. Circuit diagram for a heat sensor amplifier. The light sensor circuit is the same but uses an ORP12 LDR for R1.



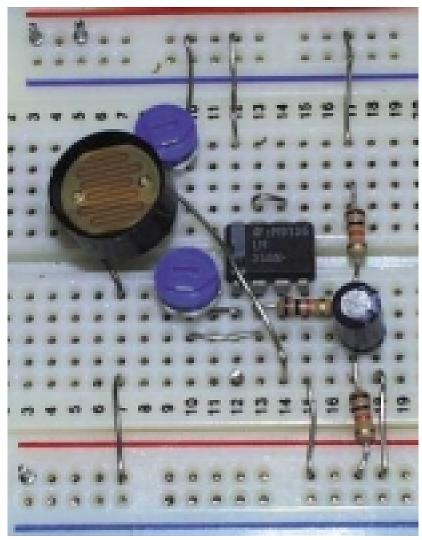


Fig.8.6 and Photo 8.6. Breadboard layout for the circuit of Fig.8.5. Note that the sensor (R1) in Fig.8.6 is not shown to scale. In the photo an ORP12 LDR is shown. Ignore location numbers in photo.

window value of 2·86V when the opamp output only drops to 0·5V is thus 82kΩ.

This method of calculation assumes, of course, that the opamp's swing range is indeed uniformly between the power line levels.

ALTERNATIVE WINDOW SETTING

An easier (but less elegant) way, of course, is not to do the ratio calculation at all but to cheat: use a 100kΩ preset as a variable resistor and adjust its wiper until you get what you want!

Jesting apart, if you do actually require a precise window value applicable to many copies of the same circuit, then a preset *must* be used since, as we have stressed in previous discussions, the "nominal" values of resistors are unlikely to be exactly correct (except in the rarest and unpredictable circumstances), besides which the output swing range of opamps also varies according to manufacturing tolerances.

Another hysteresis control and calculation technique is shown in the computer demo program *Opamp – Comparator + Hysteresis* *(For anyone who is new to this series, this demo software is available for free download from the EPE Online Library at* **www.epemag.com**, *Ed).* There the bias voltage is assumed to come from a source that does not have a significant resistance, from another battery, for example, or another buffer opamp.

PRACTICAL HYSTERESIS

From the simple maths, back to practical levels: play around with the circuit of Fig.8.3 using different adjustments of VR4 and with different values for resistor R4. You might even care to use a preset for R4 and take various resistance and voltage readings and see if you can calculate appropriate values to meet differing conditions.

It is also worth noting and experimenting with the fact that the varying signal can be brought into the opamp's non-inverting input via a resistor and still use positive feedback via R4. In this case, you would connect the wiper of VR4 to the inverting input in order to set the basic bias.

There is a condition, though: the signal coming into the input resistance should not be affected by the changing conditions on the opamp input caused by the changing states of the positive feedback across R4. At present this won't happen because the signal is coming from the output of the buffering opamp IC4b (which is said to be a *low-impedance source*).

However, if the signal were to come direct from IC1a pin 1

(which is said to be a *high-impedance source* due to the resistance of VR1 feeding into capacitor C1), then the positive feedback would adversely affect the oscillator circuit.

SENSOR AMPLIFYING

When you experimented with a thermistor and LDR (light dependant resistor) in Part 3, some of the experimentation was in conjunction with the oscillator circuit. The sensors were connected into the circuit so that the output frequency changed according to the heat or light level being sensed.

An opamp can now provide you with the opportunity to amplify the outputs of both these sensors so that they can be readily monitored via your multimeter, or even via the *Analog Input Waveform Display*. The latter will show the amplified voltage as a straight line on the screen whose vertical position is relative to the sensor voltage. Connect the opamp output to the ADC circuit as you have previously been doing if you want to see the effects on screen.

A suitable circuit is shown in Fig.8.5, in which a non-inverting DC amplifier configuration is used. The breadboard layout is shown in Fig.8.6. It is suggested that you use a 100kΩ preset as VR2 with the LDR, and a 10kΩ preset with the thermistor, adjusting the wiper until a suitable resistance value is found by trial and error. In both cases, first set VR3 fully anti-clockwise to provide unity gain.

With both sensors we suggest you also construct your own *inverting* circuit, feeding the sensor/resistor junction into the inverting input of the opamp. But remember what we said about potential dividers (which is what the sensor/resistor series is) and the load resistance into which it feeds, in this case the inverting input resistor value. Using IC4b as a buffer amp, of course, will prevent this effect.

MICROPHONE AMP

We are now in position to also let you examine waveforms created from the outside world rather than an oscillator. Time to dig that small electret microphone out of your components bag.

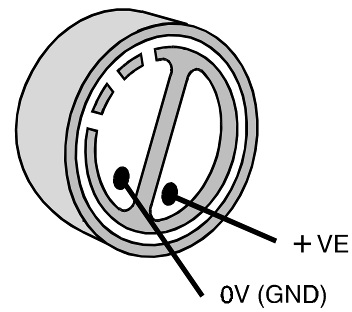


Fig.8.7. Rear view of a typical electret microphone. Other styles exist but their connections should be obvious.

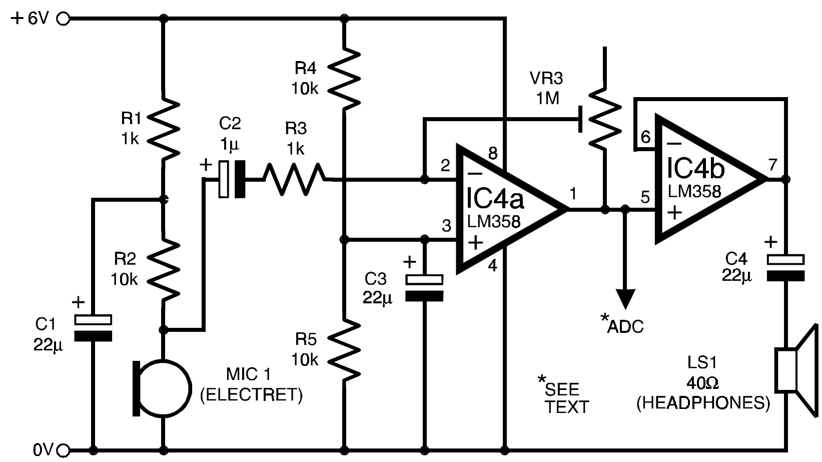
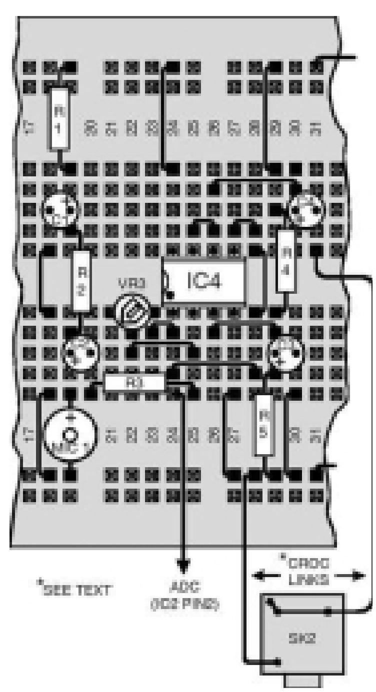


Fig.8.8. Circuit diagram for the microphone amplifier.



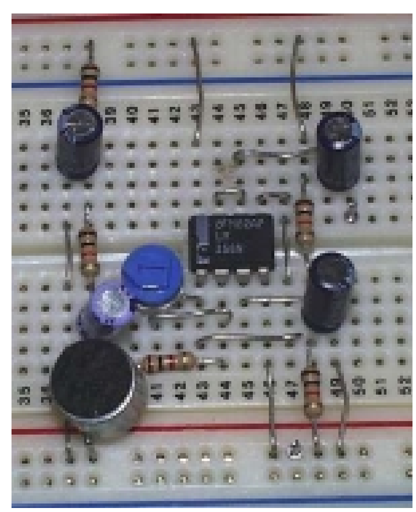


Fig.8.9. and Photo 8.7. Breadboard layout for the circuit in Fig.8.8. Ignore location numbers in photo.

Electret microphones have a small amplifying circuit already built in to them, consequently they must be used the correct way round and powered via a resistor.

First though, unless you have been very lucky and supplied with one lready having leads, you must use a soldering iron to connect a wire to each of the mic’s terminal pads. Use short lengths of the same wire you have been using on your breadboard. Fig.8.7 shows the pad positions of a typical electret mic. Take care that solder does not cause a short circuit between the pads. Leave your soldering iron switched on.

The circuit diagram and component values for the simple microphone amplifier are shown in Fig.8.8. Assemble the breadboard as illustrated in Fig.8.9, but omit socket SK2 for the moment.

You will see that the microphone, MIC1, is powered via two resistors, R1 and R2, with capacitor C1 connected between them and the 0V line. The object of R1 and C1 is to reduce the noise, which is likely to be occurring on the positive power line, caused by the presence of the oscillator around IC1a.

The power line voltage feeds through R1 and any noise peaks are mopped up by C1 (in the same way as we demonstrated capacitors charging and discharging in Part 2). As a result the noise does not reach the microphone, and so is not amplified by IC4a. The latter thus only amplifies the audio signal, which the mic picks up.

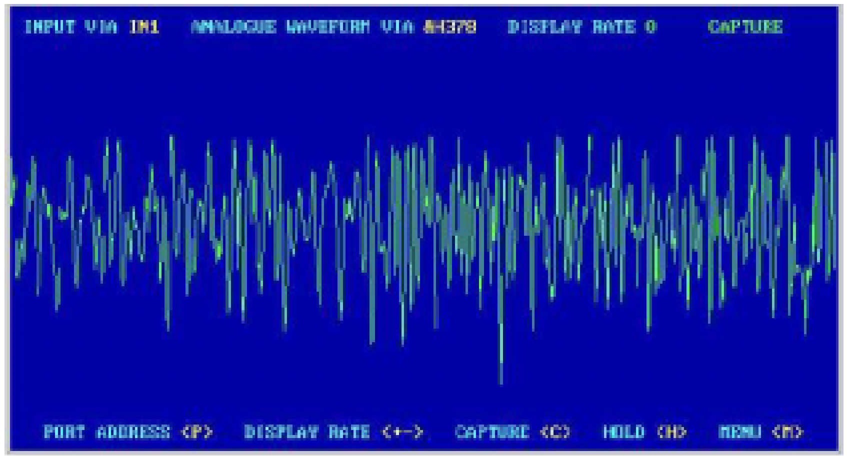


Photo 8.8. Screen dump of a speech waveform produced using the circuit of Fig.8.8.

VOICE ON SCREEN

When power is connected to the circuit, observe the waveform display on the PC screen (using the “Capture” mode) while you make noises near the mic (bring your portable radio in close, for example, or speak the traditional “testing, one, two, three!”). Increase the gain of IC4 using VR3 until you can see the

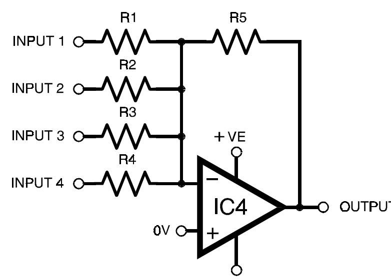


Fig.8.10. Basic mixing or summing circuit. Note that the output is inverted.

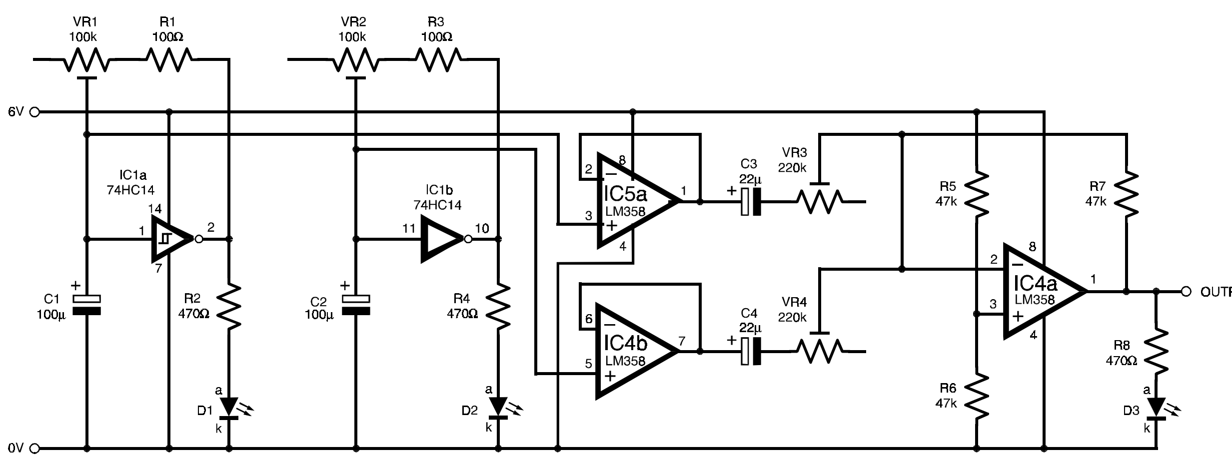


Fig.8.11. Circuit diagram for two oscillators whose outputs are buffered and then mixed into a single composite output.

waveform response to the noises. It again has to be said that modern fast computers will display the effect better than slow machines.

The gain range is variable between unity (VR3 equals zero resistance) and about 1000 (VR3 equals maximum resistance). You will recall the simple equation for calculating the gain of an inverting opamp stage from Part 7, i.e. gain = VR3/R3, thus the maximum gain is 1,000,000/1000 = 1000.

If you wished to have the minimum gain level restricted to greater than unity, an extra resistor could be inserted in series with VR3, on whichever side of it you choose. A 100kΩ resistor, for example would result in a minimum gain of 100 (100k/1k), although it would increase the maximum gain to (1M + 100k)/1k = 1100.

You can now make use of the personal headphones we recommended in the components list of Part 1, to listen to the sounds being amplified by IC4a. We stress, though, that the concept of hi-fi is not recognized by this circuit!

Solder connections (or connect crocodile clipped leads) to the jack socket SK2 as shown in Fig.8.9, plug in the headphones and reconnect the power.

We now need to point out that the type of opamp used for IC4, an LM358, is not really up to the job of powering headphones, but it should provide just enough power for you to hear the amplified sound through your headphones, which hopefully have a typical impedance (resistance) of about 40Ω minimum. Hi-fi headphones, which typically have an impedance of between about 4Ω and 15Ω, should not be used (nor should a loudspeaker).

BUFFERED OUTPUT

Because the headphones draw more current than is really desirable, the connection to them is via the unity gain buffer IC4b. To connect directly to the output of IC4a could cause distortion of the signal being amplified (try it later on and see what happens).

Again make noises near the mic and listen to the amplified result, so demonstrating the basic principle of sound amplification from mic to ear.

There are, by the way, opamps that have the capability of powering headphones, such as the L252. This too is a dual opamp, but note that its pinouts and circuit requirements are different to those demonstrated in this *Teach-In*.

To prove our assertion that the circuit can amplify noise caused by the oscillator still running in the background, temporarily remove capacitor C1 (but keep the headphones away from your ears when doing so, since the noise could be loud!). You should hear the noise pulsing in time with the oscillator's LED going on and off. Remove the oscillator's capacitor C1 and notice that the noise nearly disappears.

Beware that if you get too close to the mic with the headphones, the "howling" typical of microphone feedback from loudspeakers could occur.

MULTIPLE INPUTS

You will recall that in Part 7 last month we spoke of the virtual earth condition produced when negative feedback is used. We went on to say that this allows voltages from several sources to be fed into an inverting circuit via separate resistances, without causing a change in the virtual earth voltage level.

This same situation also means that when several signal sources are connected in this way, none of them are affected by the other, even though they meet at the inverting input.

From this it should be obvious that what this situation allows is, of course, the combining of several signals into one composite output. A basic circuit example of this is shown in Fig.8.10, and can loosely be called a *mixer* circuit.

As shown, the circuit is for use with DC voltage levels rather than AC waveforms (there are no AC coupling capacitors).

In this circuit the voltage that comes into each resistor is amplified by the ratio of *that resistor only* in relation to the feedback resistor. Thus the gain for Input 1 is R5/R1, that for Input 2 is R5/R2, etc.

The combined voltage level seen at the output of the opamp is the *sum* (addition) of the amplified voltages. For this reason, this DC coupled configuration is more generally known as a *summing* circuit rather than a mixer.

SUMMING SIGNALS

Let's examine what happens with two channels, first taking them individually (and remembering the fact that the output is inverted): Suppose Input 1 has 1V on it, the gain of this channel is set for 5, resulting in a calculated output of minus 5V. Input 2 has 3·5V on it and the gain of this channel is set for 2, resulting in a calculated output of minus 7V.

When the two processed

(amplified) signals are summed, a total of (–5V) + (–7V) = –12V appears at the opamp output.

Should Input 3 be used and it has –5V on it with a gain of 2, the calculated output is plus 10V, which is now added to the previous total, –12V + 10V = –2V.

Note that for a negative voltage to be correctly handled, the opamp must be powered from a dual power rail, e.g. a +V / 0V / –V supply.

When designing and using a summing circuit it must be remembered that the summed (total) voltage cannot exceed the maximum output swing limits of the opamp.

MIXER CIRCUIT

When multiple inputs to an opamp are in series with their own AC coupling capacitors, preventing DC levels from entering the circuit, the circuit becomes what is perhaps more generally known as *mixer*. In this role it is *waveforms* that are combined by the circuit, such waveforms as produced by speech or music, for example, although the waveforms from any sources can be combined into a single composite.

Similar restrictions apply, though, to the maximum input levels and combined amplitudes as applied to the DC summing circuit. In waveform mixing circuits a general rule of thumb to follow is that the amplified value

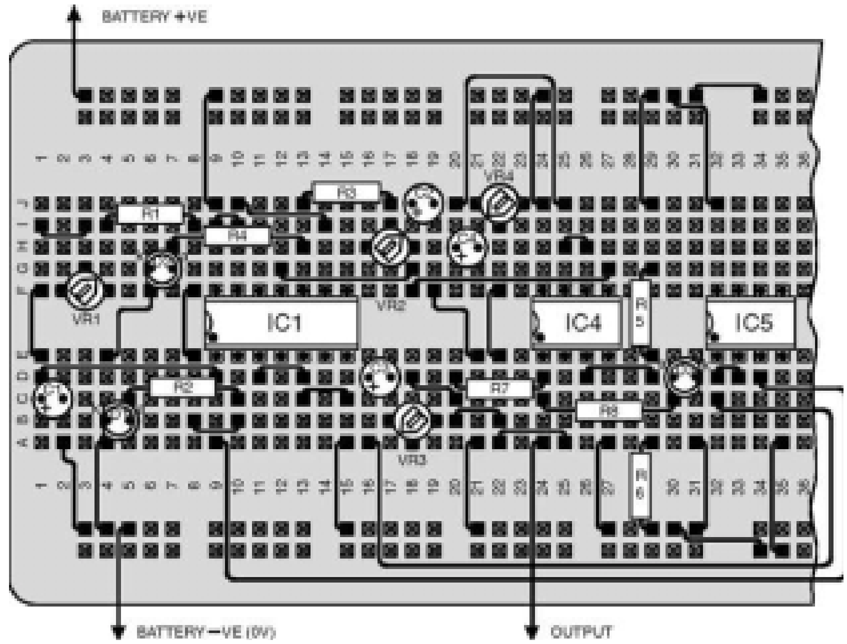


Fig.8.12. Breadboard layout for the circuit of Fig.8.11.

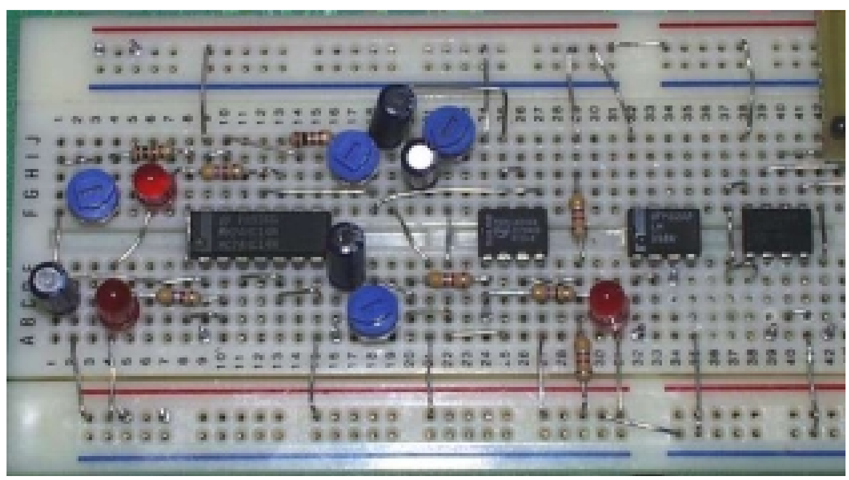


Photo 8.9. Detail of the breadboard layout in Fig.8.12.

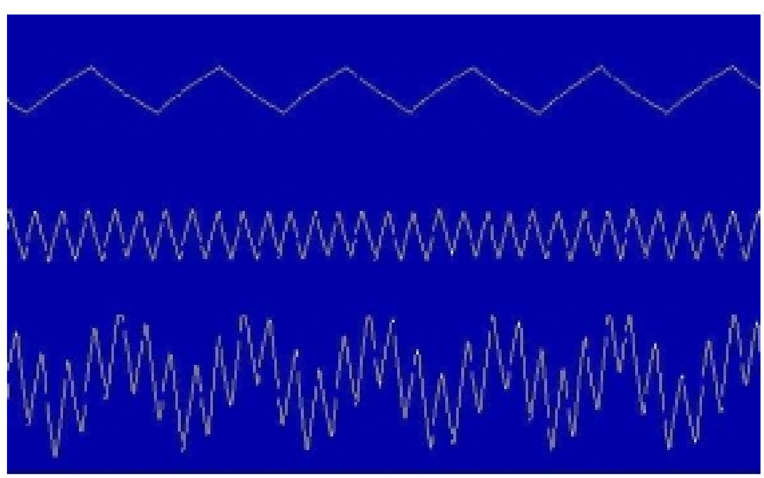


Photo 8.10. Composite of three screen dumps that illustrate two input waveforms (upper two traces) mixed into a single output (lower trace). Note that the composite does not show the waveforms in quite the correct relationships horizontally.

of any one signal should not exceed the opamp's maximum output voltage swing times the reciprocal of the total number of inputs. *What?!* you exclaim…

OK, in English then: if you have two inputs feeding into an opamp mixer whose maximum output swing is 6V peak-to-peak, the peak-to-peak value of each input should not exceed 6V/2, i.e. 3V. For three inputs the individual peak-to-peak values should not exceed 6V/3 = 2V, etc.

If individual signal amplitudes can exceed the rule-of-thumb value there is the likelihood that at some stage all signals could be simultaneously at their maximum peak-to-peak value, resulting in the clipping of the combined signal being output, i.e. *distortion*.

EXPERIMENTAL MIXER

To explore the fundamentals of a simple 2-input mixer, we suggest you assemble the circuit whose diagram is shown in Fig.8.11. The breadboard assembly is given in Fig.8.12.

Part of this circuit is already assembled on your board: the oscillator around IC1a, buffer IC4b and much of the circuit around IC4a. A second (identical) oscillator has been added, using IC1b and its associated components, R3, R4, VR2, C2 and D2.

Note that a capacitor has not been connected across the potential divider, R5 and R6, because of space restrictions on the breadboard. Normally you would include one in a circuit, as we have done previously.

We suggest that you experiment with various amounts of gain for each of the two channels, and with the oscillators set for a variety of frequencies. As well as observing all three LEDs, use the *Analog Waveform Display Program* to monitor the output of IC4a, pin 1.

Observe how clipping occurs, and how the combination of two waveforms produces other patterns, as we demonstrated when looking at waveforms in general, in Part 5.

Note also that when both frequencies have a practically identical rate, there are periods during which they tend to cancel each other, but other periods when their peaks combine at maximum amplitude. While these nearly matched frequencies shift their relationship to each other, note how the signal canceling and reinforcement is itself occurring at an observable rate. This illustrates the generation of a "beat" frequency, which we discussed in Part 5. With suitably high peak amplitudes, it should show clearly on LED D3.

PANEL 8.1 – ADDING A LEVEL CONTROL

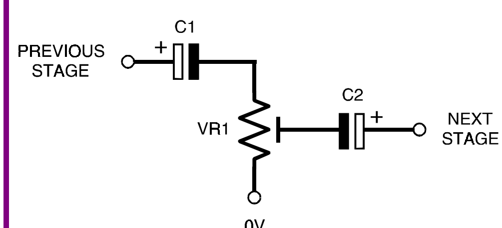
When feeding AC coupled waveforms from one circuit into another, it can be desirable to adjust the signal level reaching the second circuit. An example of this is shown in Fig.8.13.

Potentiometer VR1 may be an on-board preset or a panel control potentiometer. Typically, especially for audio level control, VR1 would be a 10kΩ log (logarithmic) component. The value for capacitors C1 and C2 might typically be between 1uF and 22uF for audio signals. For signals of other frequencies the values would be chosen to suit the frequency. This is discussed later in the *Teach-In* series.

The capacitor polarity shown is that normally required for level control circuits; the positive end of C1 receiving the signal, the negative end of C2 connected to VR1 since the latter is terminated on the 0V line.

In rare circumstances, other orientation might be required. Always consider which capacitor terminals are (or are likely to become) facing the highest voltage and orientate the polarity accordingly. In some audio circuits, this rule-of-thumb advice does not always offer the best solution, neither polarity really being correct.

To meet such situations, non-polarized electrolytic capacitors are manufactured, but are more expensive. For most hobbyist circuits, normal electrolytics are usually satisfactory. Another solution is to use two electrolytic capacitors in series, each twice the value of that actually required, with their positive ends facing outwards, negative ends joined together.



When it is the AC waveform output of a device (such as an opamp) that is required, rather that the DC voltage level, a capacitor should nearly always be used in series with the output.

For example, if volume control VR1 were to be connected to the output (IC5a pin 1) of the mixer circuit in Fig.8.11 without capacitor C1, voltage would always be present across (and current would always flow through) VR1, even if an audio signal was absent. This would be very wasteful of valuable battery power. (Note that LED D3 is only included for demo purposes.)

MORE COMPUTER DEMOS

It is now worthwhile experimenting with the other three opamp demo programs. Note that the opamps have been assumed to have a maximum output swing which is less than the quoted 5V power supply range, i.e. a 3V swing instead of 5V.

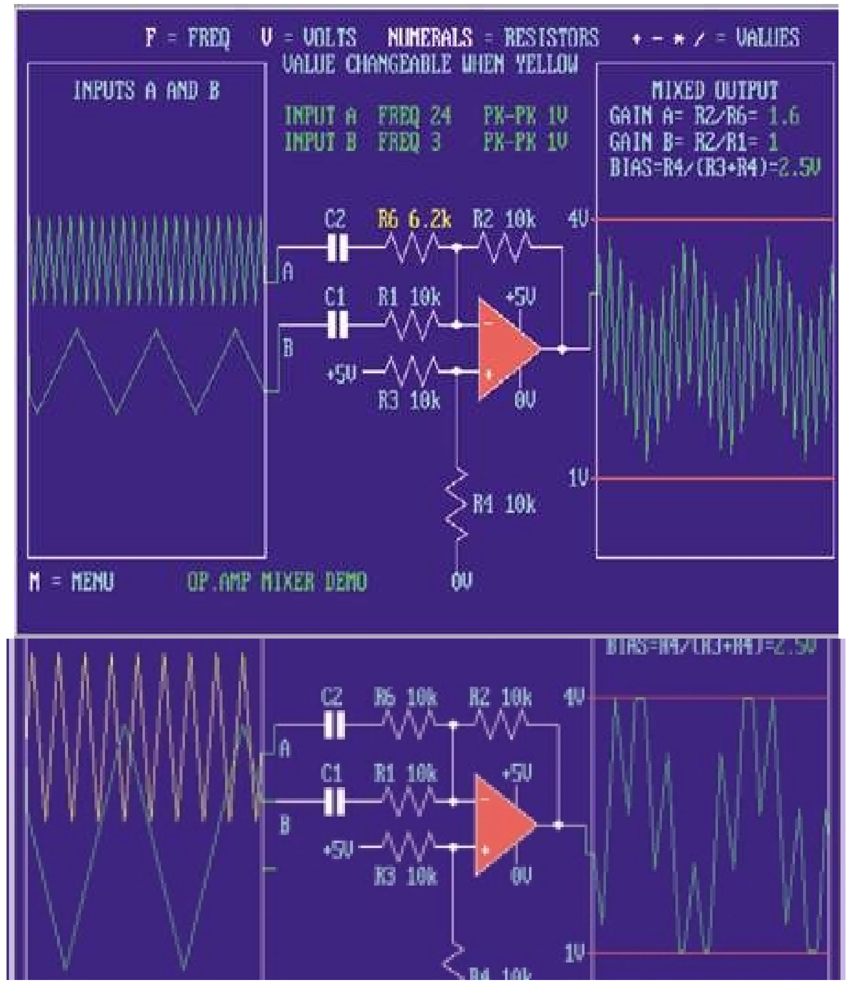
The *Opamp 2-Input Mixer* program simulates the input of two capacitively coupled triangle waveforms whose amplitude and frequency can be changed. The input resistance values can be changed to individually set the gain of each channel. The overall gain can be set by changing the feedback resistance. The bias level is also changeable via its two potential divider resistors.

Note the way in which the mixed output signal amplitude changes depending on the relationship between the input signals at any moment in time. Note how in some frequency relationships, the two signals virtually cancel each other (as discussed a few paragraphs back).

The *Non-Inverting Comparator* allows you to vary the threshold trigger level bias, the input amplitude of the triangular waveform and its frequency. The resistance values are not changeable.

The *Opamp Comparator + Hysteresis* demo is similar, but allows the values of the positive feedback setting resistors to be changed as well as the bias voltage.

The ability to superimpose a "noise" signal on the comparator waveforms has been added (use <N> and the <+> and <–> keys). Noise is a condition that can occur in any analog circuit unless measures are taken to remove or limit it. Note how the ordinary comparator is much more prone to incorrect triggering by the noise than is the hysteresis-governed comparator (also see Photos 8.3 and 8.5).



Photos 8.11 and 8.12. Screen dumps of mixer demo, the first showing "clean" mixing, the second showing waveform clipping as peaks combine.

NEXT MONTH

All-in-all, we seem to have given you a lot to keep you entertained and instructed. Not long till we have more for you, - *comparatively* speaking!

In Part 9 next month, we take the lid of transistors, so to speak. Whilst transistors as separate entities are not widely used in modern electronics, they are still encountered in some circuits and a basic knowledge of their characteristics is of benefit. They are also the fundamental building blocks used in all integrated circuits, whether they are opamps or digital electronic devices such as gates, counters and microprocessors.

They also have properties that enable some forms of signal switching to be performed more readily or cheaply than can be done using a more sophisticated semiconductor device.

Be with you again next month.

Circuit Surgery

by ALAN WINSTANLEY and IAN BELL

Our circuit surgeons provide more advice to help with readers' problems.

LOOKING FOR TROUBLE?

As part of the "deal" of pursuing electronics for whatever reason, you can guarantee that occasionally things just won't seem to work properly, if at all! Readers will agree that the more practical experience you gain in debugging and cajoling such circuits into operation, the better equipped you will be to face a wider variety of problems in the future.

Rest assured even old hands have had their fair share of headaches when developing or building their latest pet projects. Let's consider a simple case to outline a few principles of troubleshooting.

The real challenge to a constructor faced with a setback is to persevere and not become discouraged by the process of faultfinding and rectification. Sometimes you may need a little help – we all do – but you'll usually get there in the end, and you may even kick yourself when the nature of the fault is finally revealed.

It is immensely satisfying to overcome such problems and add another successful project to your repertoire. There's no doubt that experience counts for a lot, so the sooner you start constructing, the easier things will gradually become.

Note that some of our published circuits – notably *Ingenuity Unlimited* ideas – have not been proven by us and are presented purely to stimulate further thought. They are not necessarily suitable for raw beginners and we cannot provide support for them. However, when I heard that a training establishment was facing real difficulties with one "Ingenuity" design, I just had to join in the fun!

The circuit in question is the *Mini Siren Alarm* published in the Jan '99 issue. This uses a CMOS NAND gate as a low frequency oscillator, to modulate the frequency of a 555 audio tone generator, see Fig.1. The

- Split a circuit into stages (sub systems) that can be tested individually. Perhaps identify some suitable test points to take measurements. You can devise some simple tests yourself.
- Check the obvious things first, no matter how basic they seem!
- Take nothing for granted.
- Try to test everything for yourself to make quite certain that it works properly.
- Work methodically through the entire system like a detective, noting any clues, helped by any available test equipment.
- Sometimes, a function generator or signal generator and signal tracer (e.g. April's excellent *Micro-PICscope*) can be used to locate the point where an input signal is suddenly lost. More advanced hobbyists might use an oscilloscope to gather further "evidence".
- Use the test results to eliminate areas that are definitely known to be responding properly, then focus on the area most likely to contain the fault.
- Then check for incorrect wiring, faulty components or polarities, missing or incorrect parts and bad soldering. Remove suspect parts and test them out-of-circuit if needs be.

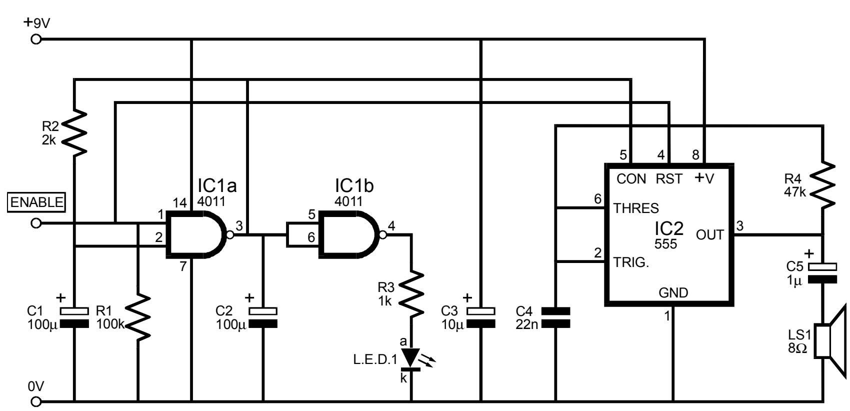


Fig.1. Circuit diagram for the Mini Siren Alarm as published in IU Jan '99

effect is to produce a two-tone siren alarm. Even a modest circuit like this can produce some challenging problems for constructors.

WAIL MEET AGAIN

I enjoyed chatting to *Mr Maurice Clarke* at Lisburn Technical Centre, whose class of 16 to 18 year old students is currently studying NVQ Level 2 and BTEC ONC in Electronics (for overseas readers: National Vocational Qualification, and British Training and Enterprise Council Ordinary National Certificate – phew!). The kindly folks here at *EPE* Towers were alerted to a problem of no less than twenty Mini Sirens which were doing anything but wail! Not even a whimper in fact. Our Deputy Editor Dave lent a hand and between us we suggested various remedies, but the problem was not to be overcome so easily.

So where to start troubleshooting with such a circuit? Things are complicated by the fact that we haven't seen the finished units, so fault finding was to be done at arm's length. Aided by Mr Clarke, the class had rightly tried many of the things which we would have suggested ourselves. My general troubleshooting advice would be as shown in the box below:

By dividing a circuit into stages and testing each one, you can gradually isolate the problem. Then start making some common-sense assumptions and eliminate those stages that are known to work correctly. In fact, as owners of Christmas tree lights will know, Golden Rule No. 1 is to check the silly things first, so that you don't look silly yourself when the fault is finally found!

POWER PLAY

In the event of absolutely nothing happening when a circuit is powered up, firstly check the power supply. In our case, is the battery flat? Are some batteries inserted with the wrong polarity? Is power reaching the circuit? Test with a voltmeter or use a bench power supply (or mains adapter) instead.

How much supply current is flowing? None or a lot? If the supply voltage is very low, either the battery is flat, or there is an excessive current being drawn (which causes the battery's terminal voltage to drop).

A "short circuit" in the project could draw considerable current (several amperes in the case of alkaline batteries), so if necessary measure the current with an ammeter, starting with a *high range* first. Although I have never known a direct short circuit myself, don't rule anything out at this stage: keep gathering evidence and clues.

Experience says that a CMOS chip draws next to nothing, and a bipolar NE555 timer will draw only a few milliamps, so I'd expect to see an initial current of a milliamp or two as a rule of thumb. If there is no sound to be heard, a high current (say anything from 50mA to 100mA or higher) indicates a component fault (wrong part or location, or a wrong polarity, maybe with a part about to go up in smoke), or a soldering fault – perhaps a short circuit caused by excessive solder being used or stray whiskers of solder.

Detecting no current flow at all would be surprising, and indicates an "open circuit" somewhere or no power being delivered. If the batteries are all right, perhaps the battery clip or holder are faulty (which has happened more than once), or a wire is broken, e.g. severed by wirestrippers.

Let's assume that the power supply is intact, but we're still greeted by silence. What then? Perhaps a wire has come off the loudspeaker or it is somehow faulty. Test it with an ohmmeter if necessary.

We could then test the sound generator. Looking at the 555 in Fig.1, its reset terminal (pin 4) is pulled down by a 100k resistor. Try pulling pin 4 high to the positive supply instead, and also let pin 5 (control voltage) float.

This should "enable" the oscillator and a continuous tone should be heard. This was indeed the case when I tested it on a solderless breadboard. We can now deduce that the 555, loudspeaker and battery are all working properly.

Reconnecting pin 4 and pin 5 back to the CMOS gate re-introduced the problem. The audio tone became completely unstable and was not being modulated at all. We felt then that perhaps adding some supply decoupling might be useful. A 100nF polyester across the supply might stabilize the circuit, given that a 10uF electrolytic was already there to help with this.

It made no difference, but from experience this *does* sometimes help when there are several oscillators running on the same supply. A CMOS chip may also be unstable if any unused inputs are allowed to float. They should preferably be tied low, and this is not always

shown on circuit diagrams.

UNLOCKING THE GATE

We decided the problem must center around the NAND gates. We can see how one gate IC1b is merely being used as an inverter to drive a light-emitting diode (LED), so we can take that part out altogether.

That leaves us with IC1a, a NAND gate with a large *RC* network on its input. It is here where I finally focussed my attention. In practice, logic gates are ill-equipped to deal with slowly varying signals, and one should think in terms of a "Schmitt-input" NAND gate instead, which has the special property of hysteresis.

How a slow ramp signal input is translated by a Schmitt NAND gate into a fast "snap action" transition is shown in Fig.2a. The Schmitt is untroubled by slow changes, and also has excellent noise immunity, so that it will change states with surgical precision even when the input contains a lot of superimposed noise that would send an ordinary NAND berserk! – I'm sure that's what was happening here.

Hysteresis means that there is a difference between the gate's positive-going threshold and the negative-going one, see Fig.2b. This does wonders for stability and preventing false triggering. My next step, then, was to swap the original gate IC for a Schmitt NAND, the 4093. Both chips are pin-for-pin compatible. Lo and behold, the audio siren burst into song!

That example highlights how you must develop a train of thought when unraveling a circuit fault. Even a simple circuit can hide an obscure problem which, admittedly, a novice or trainee may struggle with sometimes. The training center students (hello everyone) had in fact done everything right, but were faced with the extra challenge of battling with a circuit that needed just a little tweak. Only those with practical experience of CMOS logic would have known what to do, so as I said earlier, there may be times when advice may be needed.

MORE ON FAULTS

The next even simpler example of fault finding may also help inexperienced readers to develop the art of logical thinking. Remember, take nothing for granted until you've tested it for sure, and work methodically through a circuit until the fault is pinpointed.

The circuit consists of a battery, bulb and switch – nothing special except that the battery is a rechargeable 6V lead acid unit, the switch is a "trigger" microswitch and the bulb is a 1.5 million candlepower (it says here) halogen searchlight!

This brand new unit arrived on my bench in a totally dead state, even though it had been charged the previous night and tested out OK. It wouldn't work at all and had me foxed for hours. The removable rechargeable battery tested about 6V and seemed to have charged up, so the battery and recharger unit appeared to be all right.

I could have quickly tested the battery by putting a heavy load on it (e.g. a 1 ohm power resistor) and measured the

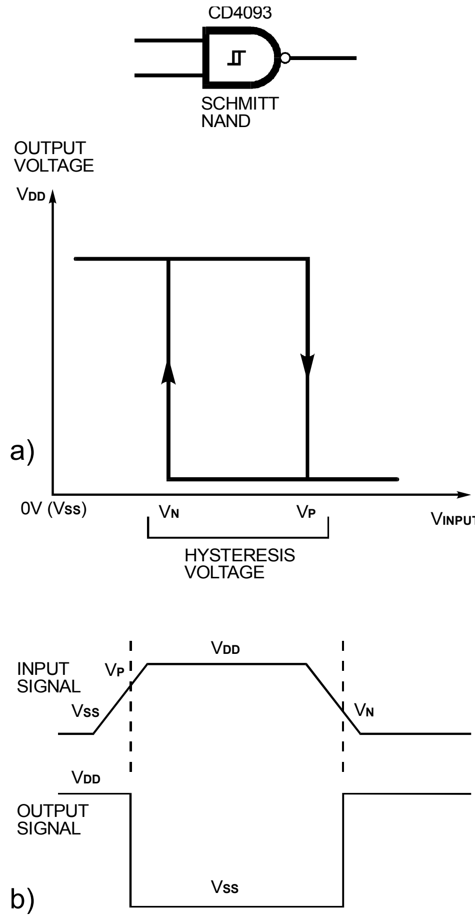


Fig.2a. Typical Schmitt trigger hysteresis curve. The difference between the two triggering points is called the hysteresis voltage. (b) illustrating how a slowly rising or falling waveform is translated by a Schmitt NAND gate into a sharply falling or rising edge.

voltage again. *Lead acid cells aren't to be messed with though, and care was needed not to short the terminals or this could have caused burns or started an electrical fire.*

Testing the obvious things first: had the 6V halogen bulb blown? I couldn't test it on a car battery but an ohmmeter confirmed it was OK. There isn't much left to go wrong: the microswitch worked properly (I checked the contacts to make sure), and the searchlight's

wiring continuity checked out all right. Still wouldn't work!

What about the lamp's battery contacts? These were traced through and the wires were intact. The phosphor bronze contacts looked new and undamaged. A further test showed that power wasn't reaching the switch and bulb. Since the battery was known to be charged up, and everything else had tested out, that only left the removable battery not making proper contact with the searchlight. Even then, the contacts looked all right to me.

After much muttering and dark oaths, for some inexplicable reason the lamp suddenly started working again! A sliver of loose plastic from the injection molding was later found near the battery contacts, and I assumed that this must have broken away and caused one of the contacts to break the circuit – a simple fault which never-the-less took nearly two hours of messing about to resolve. Troubleshooting is 80 percent detective work and 20 percent experience with a bit of good luck thrown in as well.

If you ever experience problems with *EPE* constructional projects, help is never too far away and you can usually write to the designer c/o the Editorial address, explaining all the symptoms along with any test measurements, and with luck the original author may be able to offer some pointers. Also consider asking in the *EPE Chat Zone* message board on our web site.

Note that we are not usually able to publish authors' E-mail addresses, and we cannot offer help on projects more than five years old. Meantime I hope the above offers a few pointers to help you develop your own fault-finding routines. *ARW.*

COMPUSERVE 2000

MIGRATION TO COMPUSERVE 2000 MAY NOT BE TROUBLE-FREE FOR "CLASSIC" USERS – AS BARRY FOX REPORTS.

Internet E-mail services such as Freeserve are free, but users must pay the cost of the access call to the UK node. This makes access from abroad difficult and very expensive. The two long-established E-mail services, AOL and Compuserve, charge a monthly subscription rate but offer access through local nodes in most countries. A year or so ago AOL bought Compuserve and has been trying to integrate the two infrastructures. While AOL remains largely unchanged, Compuserve has launched a completely new service called Compuserve 2000, which uses the same software as AOL, with only cosmetic differences.

Compuserve 2000 slid onto the market without any formal launch or press briefings. The software is given away on magazine cover-mount discs, and mailed to existing "Classic" Compuserve subscribers. Compuserve's Help Line was ill-prepared to answer queries from users who tried using the discs and ran into trouble.

The disc contains important utilities, but there was nothing on the sleeve note to explain where they are, what they do and how to use them. Compuserve's management, press and PR team has been in a state of flux since the takeover. Journalists and users alike have been given incorrect and contradictory answers to questions on issues of pricing, policy and technology.

Mishandled

Recently, a Compuserve spokesman admitted: *"The conversion from Classic to 2000 was mishandled. The two services are completely different and this was never communicated. It was a mistake and wholly regrettable. We are absolutely committed to supporting Classic if people want to stay with it".*

Previously Compuserve had said: "We are giving more attention to the service itself than to the technology used to deliver it, e.g. the new CompuServe Portfolio and TravelAgent products."

The first CS2000 discs triggered an installation process that asked existing subscribers for their ID and password. But this was not their existing ID number or name alias. Confusingly, it was the free trial code on the disc sleeve. Compuserve's Help Lines were quickly clogged with long queues of enquiries.

Hopefully this has been changed on later versions. But one thing cannot change for the better. Existing Classic subscribers must choose a new name. From then on, mail addressed to the old Compuserve name or number is automatically forwarded. But once you have converted one PC to CS2000 and chosen a new name, you are obliged to convert every other PC you ever use because their old-style software can no longer receive mail.

No Escape

On the original CS2000 discs there was no escape from the installation procedure. The only way out was to crash out with Ctrl-Alt-Del. This was a dangerous trap because it is an odds-on certainty that Classic users will not be able to keep their existing name alias. Every imaginable name and close variant has already been taken.

This is because CS2000 shares a database with AOL, so literally tens of millions of names have been taken by AOL users long ago. The system offers only dog-ends like Bill7453. Every attempt at choosing something else is likely to fail. Once the user has accepted a dog-end, either by accident or in exasperation, it is too late to change.

One trick is to use phonetic spelling. I had to settle for **barryphox@cs.com** and now get messages to Mr. Phox. Another trick is to tack the letters UK onto the end of a name and hope no-one got there first.

Foreign Surcharges

International access has changed too. Some foreign numbers can only be dialed from inside the foreign country.

This makes it impossible to set up a laptop in advance of a foreign trip and check access before leaving home. Compuserve has not been able to explain why access by GSM cellphone, e.g. in Berlin, is unreliable, with calls repeatedly dropping after connection, but sometimes working with the same settings.

This matters because CS2000 introduces roaming surcharges. Whereas it cost only the price of a local call to access Compuserve in foreign lands, there is now a billed surcharge.

This varies from country to country but is unlikely to be less than 2.50 UK pounds and can be 20 UK pounds. Compuserve has been giving completely contradictory advice on whether this is per access or per hour. The latest assurance is that it is per hour, on top of whatever call charges are made to access the local node. It is best to check on line with GO PHONES, Communications Surcharges, before leaving home. Advice from the CS2000 Help Line has been unreliable, and whereas this used to be on a freephone number, both Classic and 2000 users must now pay at national rate.

When ISDN connections by Motorola/BT Ignition Terminal Adaptors recently failed, it took a month of wasted calls and red herring advice before the Help Line discovered that there had been an undocumented change in the CS2000 network protocol.

A new service called CS Webmail allows international access through ISPs (**http://cs-mail.compuserve.com**). So it should be possible to collect mail through an Internet Cafe. But once someone has ISP access to the Internet they can equally well use it with a free E-mail service such as Hotmail, without the need for a Compuserve or AOL subscription.

Netscape On Line

Less than five percent of Classic users have migrated to CS2000. Some of those quickly regret it but find themselves trapped. Although it is possible to revert to Classic, the process takes several days, during which time all incoming mail is lost. After that any mail sent to the 2000 address will be lost because there is no provision for backwards routing from 2000 to Classic.

AOL/Compuserve clearly see the writing on the wall. The company is already offering UK users a free Internet/E-mail service called Netscape on Line, which competes directly with Freeserve.

NEW MAPLIN CATALOG

Maplin Electronics has radically redesigned its bi-annual catalog. It is segmented into seven discrete product “worlds” of Communications, Components and Cable, Computers, Electrical, Leisure and Hobbies, Sound and Vision, and Tools, encapsulating all the existing product sections found in previous catalogs. The new catalog contains around 20,000 products, reduced by rationalizing the range from the previous 37,000 or so items.

The new catalog includes many additional features, including substantial price reductions, over 50 UK pounds worth of vouchers and improved photography. The single CD-ROM catalog comes with a comprehensive search facility that aids product browsing. Product pictures, technical specifications, an order facility and a data sheet library collectively enhance this latest version. For more information contact Maplin Electronics, Dept EPE, PO Box 777, Rayleigh, Essex SS6 8LU, UK.

Tel: +44 (0) 1702-554000

Fax: +44 (0) 1702-554001

Email: bayo.alaba@maplin.co.uk

Maplin have also just redesigned and relaunched their web site at **www.maplin.co.uk**

Precision Temperature Sensor

National Semiconductor has launched the LM92, the latest addition to its digital temperature sensor family. The revolutionary LM92 is claimed to be the world’s most precise digital temperature sensor with up to ±0·33°C linear accuracy.

In addition to giving a digital temperature readout, the LM92 provides an integral thermal window comparator making the design of complete temperature control systems easy. The upper and lower limits of the window can be programmed via a two-wire serial bus interface.

The device’s supply voltage range is 2·7V to 5·5V and a low power (5uA) shutdown facility is included. Temperatures be-

tween –10°C and 150°C can be monitored.

You can browse National Semiconductor's web site at **www.national.com** for more information on the LM92, and other National products.

Cheaper Solar Panels

From April 1st this year, solar panels qualified for the same reduced VAT rate as applies to domestic fuels, namely 5% rather than 17·5%.

Energy Minister Helen Liddell says *"The green technologies offer heat and power without the penalty of emissions. The Chancellor has cut the price of this environmentally sound technology … we are bringing down the cost of both solar hot water systems and PV panels for electricity generation".*

More information can be found on web site **www.dti.gov.uk**

Hacking Expense

A 15 million UK pound project which offers potential defense against the paralyzing attacks by Internet hackers is to be funded by the Department of Trade and Industry. Minister Patricia Hewitt said that "We have recently seen to devastating effect how hackers can penetrate and disrupt services offered on the Internet. The six projects I have approved will help us combat these Internet criminals". More information can be found on web site **www.dti.gov.uk**

LET'S DO IT

A most remarkable CD-ROM has been received here at HQ. Entitled *Let's Do It – The Practical Electronics Book*, it is a really comprehensive tutorial "book" which aims to help you learn about electronics, and to do so in an enjoyable way.

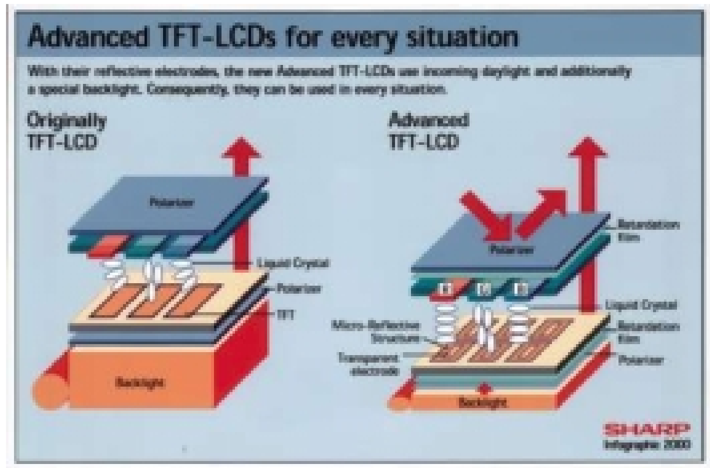
It has been written by Eric Edwards, who spent two years doing so. It is obvious that he has thoroughly enjoyed writing it and utterly delights in everything to do with electronics. Eric describes the work as offering a *"fun way of learning by doing"*. It certainly appears to live up to this description.

The CD-ROM has chapters dealing with how to set up your own workplace, tools, equipment and components needed to get started. Soldering and laying out of components are dealt with, along with details of producing your own PCBs.

In the Applied Theory section, it explains things in a "down-to-earth" fashion. There are experiments and projects splattered throughout the pages. Analog, digital, radio, TV, computing, and even PICs, are subjects which Eric examines with caring attention.

There is a good reference section, which covers symbols, useful formulae, tables and facts, plus acronyms, abbreviations and "rules of thumb". The "book" ends with fault-finding and references to further read-

BETTER NOTEBOOK DISPLAYS



Sharp recently announced that they have developed especially high reflective LCD color displays, which will enable equipment such as notebook computers to be used more readily outdoors. Many of you will be aware that currently displays used in such equipment use back-lighting and thus may only be used in a low brightness environment, with the display becoming unreadable in bright sunlight.

The new technology developed by Sharp combines two structures on one substrate, respectively optimized for active back-light (transmissive) or passive ambient (reflective) lighting. Only 0·08 watts are needed in daylight without back-lighting, which is the optimal solution for mobile phones and other portable battery operated devices.

A further benefit is that the reaction time is only 50ms, guaranteeing moving pictures without annoying plumes and with a viewing angle always at least 70 degrees in all directions.

For more information browse **www.sharpmed.com**

ing, electronic magazines, clubs and associations.

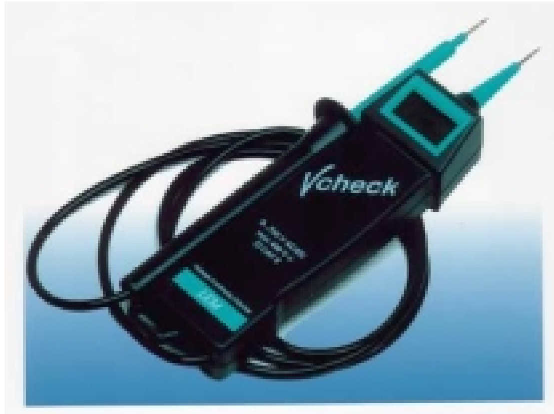
Interspersed with autobiographic reminiscences, this 420-odd pages of practical information really is quite enthralling. The CD-ROM runs in Windows 95/98 under Adobe Acrobat version 4 (which is included) and costs a mere 10 UK pounds, plus 1 pound shipping and handling (1.95 pounds S&H Europe, 2.95 pounds S&H for the rest of the world).

Send for your copy to Eric Edwards GFW8LJJ, 11 Old Village Road, Barry, Vale of Glamorgan, CF62 6RA, UK.

Tel: +44 (0) 1446-740498

E-mail: gq8ljj@tesco.net

RCD TESTER



LEM UK tell us that in line with increased demand for accurate test instruments that are simple to use, they have developed the new V-check voltage and continuity tester. This has all the features you would expect from a simple tester of this type, but it also has the ability to check the operation and wiring of RCDs (residual current devices, or circuit breakers) by means of an automatic internal load.

V-check measures voltages from 9V to 700V AC and DC at a resolution of 0.1V with an accuracy of ±3%, even if its internal batteries are completely exhausted. As a continuity tester it has a range from 0 to 500kΩ at a resolution of 2mA. For more information contact LEM UK Ltd., Dept EPE, 1 Penketh Place, West Pimbo, Skelmersdale WN8 9QX, UK.

Tel: +44 (0) 1695-720777

Fax: +44 (0) 1695-50704

E-mail: luk@lem.com

Readout

***John Becker* addresses some of the general points readers have raised. Have you anything interesting to say? Email us at editor@epemag.com!**

WIN A DIGITAL MULTIMETER

The DMT-1010 is a 3 1/2 digit pocket-sized LCD multi-meter which measures a.c. and d.c. voltage, d.c. current, and resistance. It can also test diodes and bipolar transistors.

Every month we will give a DMT-1010 Digital Multimeter to the author of the best *Readout* letter.

* LETTER OF THE MONTH *

SPUTNIK RECALLED

Dear EPE,

I have retired after some 41 years working for the best broadcasting co-operation in the whole world and must say how I enjoy my monthly copies of *EPE* and using my soldering iron again.

Your articles titled *Technology Timelines* really stirred the cobwebs of my early days as a young engineer working at the BBC's Receiving Station at Tatsfield in Kent/Surrey and brings to mind the Geophysical Year (July '57-Dec '58). We were particularly interested in the sunspot activity which caused total ionisation of the short wave radio spectrum, resulting in loss of short wave propagation and consequently total loss of signal from around the world with what is nicknamed a "Dellinger" blackout.

We used to check the sunspots daily through a telescope projected onto a white cardboard display where the sunspots would show as black dots progressing across the equator of the sun. The more the spots, then lots more blackouts were the norm, with various lengths of duration from 10 minutes to as much as over half an hour.

In Messers Brown and Maxfield's article they date Sputnik 1 as October 4th 1957 and well I remember this amazing event when senior engineer Mr Cyril Dobner was on duty on nights at Tatsfield, trawling the short wave bands measuring the American station WWV clock from North Carolina (at 2300 hrs). A frequency check for Westerly propagation was checked out at 5/10/15MHz and finally 20MHz, whereupon he found this enormous signal with no normal

1-second time clicks on it, and it was only when he checked with a BFO that he discovered that the signal had Doppler shift on it, which shifted from 20.008MHz right down to 20.005MHz and then it faded away!

It was shortly discovered by our Mr Geoffrey Judson that there were two plain carriers which were switched between 20.005MHz and 40.010MHz and consequently sounded like pulses. The so-called "Morse Code" was only produced by switching a beat frequency oscillator against these plain carriers (which were all equal in length by the way) and one had to manually chase the signal to nominal frequency to hear anything at all. We measured the signal at plus 30mV per metre at peak, received with our own Research Department designed remotely steerable wideband helix aerial, which we originally used for chasing Echo 1.

Radio Moscow then announced to us that the world's first satellite had been successfully launched and was orbiting the earth every 86 minutes, proving that the captured Russian/German scientists were better than the American/German scientists. In those days we were the only people that checked the world's radio spectrum. As far as it was alleged, Jodrel Bank went home on Friday evening and Kettering Grammar School didn't enter the satellite business for years to come.

It was later in 1962 that Telstar was launched and I know that we engineers watched TV as the Post Office were chasing its radio/TV link. It was ages before the shout went up that one searcher had "found it" much higher than the pilot signal was supposed to be.

As far as we know, we were the first to measure actual radio Doppler shift to be broadcast and if only the GPO had asked us to search for that signal I am sure that a much longer television picture would have resulted for the first transatlantic audience to witness. All the best for

a super magazine and thanks for the memory, now back to that kids' "Brain Game" kit, for my grandson of course!

Dave Bishop, Tatsfield, via the Net

How fascinating that you experienced the event "as it happened". I too recall the event but only as a childhood memory of the radio news broadcasts and newspapers. I also recall the disbelief of many of the adults around me, including teachers, who thought that the whole thing was a hoax, stating that science fiction could never become science fact. Yet we now all take satellites as an inevitable part of life.

VIDEO CLEANER

We have been receiving a number of letters from readers about the Video Cleaner (Feb '00) and which we have been forwarding to the designer, Mike Delaney. Mike has kindly sent the following "cover-all" reply (while "180 miles east of Fortaleza, Brazil, heading west to the Carnival, temperature 32C, skies clear and blue…"):

One reader (in Florida) queried the value of capacitor C7, 22uF, suggesting that it should be changed to 6u8F. I arrived at the value chosen by experimenting with my domestic set up, and that of my friend. In my design, apart from the oscillator components, the only component values which are "Cast in Concrete" are the gain-determining and impedance-matching resistors around the two multiplexers, IC3 and IC4. I experimented with the R9/C10 network on the LM1881, and decided that the manufacturer's suggested values worked well with my board. I think in this reader's case the difference in capacitor leakage (mine was nothing special, just a standard junk-box cap) or TV input impedance might be to blame.

A Letter From America asked whether the circuit would work with the NTSC system they have over there. The circuit is designed for use on PAL systems, mainly when making a back-up copy of a "Noisy" tape or if "Interference" is experienced. Unfortunately, I do not have access to NTSC VCRs or tapes for testing. I think it may only be a case of altering the timings; I would be most interested to hear if that gentleman has any success in this direction.

The unit is not designed to interface and de-scramble Satellite video, sorry.

Mike Delaney via the Net

Thanks Mike – but why go to Brazil when Wimborne has its own Carnival, and without that frightful heat?!

REASSURANCE AND SUGGESTIONS

Dear EPE,

Yours is a great magazine and as a regular subscriber (I'm laying it on thick now) I don't think you need concern yourselves with the "complaint" E-mail referred to in *Readout* of the April '00 issue. The sender of the E-mail will not find a better magazine or any more informative and practical advice or articles around. The web sites the complainant so obviously favors may have wonderful search engines but also invariably have no true knowledge to pass on.

John Becker, at the end of the *Micro-PICscope* project (April '00) asks for suggestions for PIC based projects and I have a suggestion:

The idea is for an electronic device which will peak detect audio frequencies fed it from an electric guitar, remove the fundamental frequencies (the notes being played) and convert these to a MIDI data stream on a DIN output port and a PC joystick style output port. Two outputs are required as MIDI uses such low currents that "Y" connectors are not suitable.

How about a six-transducer add-on that would enable the above project idea to detect the notes being played by each string, analyse them at the same moment in time and code the chord (notes played in parallel) data. Oh, and make the tea!

I've enjoyed all the PIC projects published and particularly the MIDI and musical ones: from the *MIDI Analyser* in May '96 through the *MIDI Handbells* (May '99), *PIC-olo* (Aug '97), *Mini Organ* (Dec '97), and *PIC-a-Tuner* (May '97).

If you look at the web site **www.qvox.com** and their product the GVOX Guitar Pickup you will find where I got the idea for the chord data being detectable. I guess they use each transducer to pickup a separate signal, this being the reason you need to fit a new transducer to your guitar.

Owen Whitefield via the Net

In one respect, Owen, what you propose seems quite feasible, although it would take a guitar playing electronics designer to achieve it (regretably I never got on well with guitars, fingers and correct notes!).

On another level you've hit a sore spot with this suggestion, which implies the additional question of how you could achieve the same ends without several transducers. Some time back I spent several months trying to write software that would analyze the frequency content of an harmonic-rich musical theme. I failed!

As I reported in Readout *(my memory doesn't say when), I eventually discovered that major chip and software companies were also working to crack the problem, but at that time even they had not succeeded.*

While it is easy to establish the frequency of individual musical notes, the situation becomes immensely complicated when there are two or more notes occurring as a composite.

So, all in all, thanks for your suggestion, but personally I won't take you up on it! However, does any reader think he or she might achieve frequency analysis simply and in real time, either using separate transducers for individual guitar strings, or just software to extract the data from a single mix of notes?

PORT INVERSION

Dear EPE,

We actually spoke on the phone a few weeks ago, when I called to query some of the things in your excellent *Teach-In 2000* series. The main problem that I had was that I was getting no joy from the computer interface which was set up in the Feb '00 issue. Since then I had no more luck and resigned myself to having gone as far as I could with *Teach-in 2000*.

However, when I was browsing through the letters page of the April '00 issue I spotted the letter from Hitesh Lala. Trying his suggestion, lo and behold life in the interface. As soon as I reversed the polarities, it started working as expected except that where you say I should have logic 1s on the screen, I have 0s, and vice-versa. I will now explain exactly what I am getting as I follow the instructions on pages 134/135 of the Feb issue.

Firstly, the output box: with the meter –VE to PCB ground, and +VE to any output pin, I get 0V when the byte is set to 1 in the box and a deflection to the left when the byte is set to 0 (I should have noticed this before). So I reverse the meter so that meter +VE is to PCB ground and meter –VE is to the output pin. Now the circuit behaves as described except that I get +5V when the byte = 0 and 0V when the byte = 1.

Secondly, the input boxes: when first plugged in the left-hand one reads 01111000, and the right-hand one 00011111 (in fact this is nearly what your photo at the top of page 135 shows). When I touch battery –VE to PCB ground and battery +VE to any input I get nothing. When 1 touch battery +VE to ground and –VE to any input, the respective 1 in the right-hand box changes to a 0. Completely back to front.

I work around the periphery of electronics on the repair side, so I am familiar with soldering and which leads go where on a multimeter. These possibilities for mistakes have been checked. My meter is connected properly and my soldering has been subjected to continuity tests, and checks out. My computer's printer works perfectly from the same port. It is a Packard Bell 486 that I have had for about five years.

Needless to say it is a credit to the series that I managed to get as far as I did. That working oscillator was my pride and joy for weeks until all my friends had seen it 20 times and my partner, who is a complete technophobe, almost understood it herself (guess who programs the video in our house). I do find it absolutely fascinating and the possibility that I could communicate with my own computer was a real boost. So it is with disappointment and hope that I relate this tale.

Chris Cooper
Malton, North Yorkshire

This port problem has been experienced by a handful of other readers as well, and we cannot establish why it should be happening. All of the many computers of various ages, makes and capabilities that I have tried with the Teach-In board all work successfully.

We wonder whether the next letter, from David Godbolt, might hold the clue:

PORT CABLES

Dear EPE,

On testing the Centronics to computer cable, I could not get a ground (0V) connection relative to the ground of your *Teach-In* board. So I bought a new cable for it thinking that mine was faulty. This did not work either, so I took it back and explained the problem and they replaced it with a super state-of-the-art IBM compatible, bi-directional, etc., cable. This worked. I got proper readings on all eight pins, but only 4V. The cable was 7.5 meters and I thought perhaps the voltage drop was due to the length of the cable so I took it back again and got a replacement (same thing but 1.5 meters) – and guess what, it did not work!

It turns out that with each PC to Centronics cable there seems to be at least three differ-

ent wiring arrangements, even though the fittings at each end are the same:

- o) Type 1 – no pins connected to ground, but case connected to ground.
- o) Type 2 – one pin only connected to ground.
- o) Type 3 – at least five pins connected to ground.

Type 3 was the only one that worked but I could not get that one in a shorter length, so only got 4V.

Question 1 – would 4V be sufficient anyway?

Question 2 – Does anybody else have this problem? In the shop they seem to think that it is a very special requirement. Is a special cable needed?

David Godbolt
via the Net

We were totally unaware that PC to Centronics printer port cables might differ. We have numerous such cables and all work interchangeably and we have never had to specify a particular type when purchasing new ones. It had been assumed that IBM PC-compatible computers would all be identically compatible in respect of parallel printer port connections. Would readers who know about such things please advise us.

The Teach-In board was designed to minimise the number of soldered connections that inexperienced constructors would have to make. Consequently, only one 0V connection was incorporated, that being the one at the "front" of the connector.

Readers who are having problems which might be attributable to the printer port connection should try connecting all the 0V pins to the 0V pin already in use on the Teach-In board.

The IBM data we have states that Centronics parallel printer connectors have 0V at the following pins: 16, 17, 19 to 30 and 33. On the Teach-In board connector, pin 1 is that to the left of the Data Out 0 connection, pin 19 is that "behind" pin 1.

Regarding David's first question, it is likely that 4V may well suffice for the Teach-In demo circuits.

DOS ERROR

Dear EPE,

Using Toolkit V2.3 on Win 98, I get "Main program unforeseen DOS error number 62 route 6" when trying to use menu option 8 – text convert file TASM to MPASM. Same error occurs both in a Win 98 DOS box and if TK is run at the command prompt (Win98 "MS DOS mode"). I've been able to use option 5 (TASM bin – MPASM hex) OK. The screen says please advise you so please consider yourselves advised.

Malc Wiles
via the Net

To which I replied: Error 62 is "Input past end of file". This could be caused by non-text characters somewhere in the file you are importing. Malc responded:

Yes, that would be it. One of the text editors I'm using puts an EOF (CTRL-Z, 0x1A) character at the end of file. If I delete that character, the problem goes away. The message is a bit misleading because the 0x1A char is the last character in the file – there is no input past the end of the file! The big blue screen seems a touch draconian as a reaction, too, a bit too reminiscent of major Windows crashes … EOF character insertion is not unusual behaviour by (particularly older) DOS editors (I use two different ones that both do it), and I'd suggest future versions of the program should just quietly ignore anything in the input file after the END.

Thanks for comments Malc. Would that I had the time to give every aesthetic touch to my screen displays as an art form! Correct functionality has to be the prime consideration in an over-crammed schedule – candles being burned at more than two ends . . . What's wrong with MS blue, anyway? Sometime I'll look into 0x1A, it is a problem that can crop up in Basic.

FOND FAREWELL

Dear EPE,

I have received your magazine's subscription renewal form but I shall not be renewing, for the following reason:

My association with EPE goes back to 1990. I was at teacher's training college in South Africa then; studying to be a teacher of Electronics and Electrical Engineering – what is commonly known over there as "Technika Electronics or Electrical".

Our electronics lecturer (who shall, for reasons soon to be revealed, remain nameless!), during the course of our final (4th) year handed us a whole wad of photocopied notes on C&G basic electronics, digital theory etc – all faithfully copied out of EPE magazines! These stood us in good stead as supplements to our notes as we were very close to exams – I passed!

My first subscription to your magazine was in (here I go again, taxing my memory, my doctor's warned me not to do this!) 1993/4, somewhere around there! It was because of EPE's amateur radio column that I became involved in amateur radio of which packet radio is my favourite! (When my wife and I and our two boys emigrated here to Cornwall in 1998, I converted my ZR call-sign to a British Class B licence – although I'm presently inactive due to work pressures). I have delved into my EPEs on many an occasion looking for, and finding, answers to my questions about the finer points of capacitor identification (Circuit Surgery – thanks Alan!), Class A amplifier design and other such intricacies – in fact I've even cobbled together a car alarm using two separate alarm projects featured in EPE.

So to come to the reason why I won't be renewing:

EPE opened up the world of electronics for me and introduced me to its diversity (power supply design and construction, PICs, computers, amateur radio, etc). Which brought me to realise that teaching was all fine and well but clearly my interests lay else where, i.e. computers. I am now an A+ Certified Service Technician and work for a software company based in Stratford and Plymouth as their "technical support person" – I spend my days remotely trouble-shooting business PCs, and it's challenging, rewarding and fun! I have found my "niche" (for now :-)), and unfortunately I now find I have less and less time to spend on my older hobby of electronics. So rather than waste a good magazine subscription by having it lie on my shelves gathering dust, I felt it best to stop.

My oldest son is five and is being home-educated, he has a great interest in Lego, tools, and "helping dad", we've bought him a toolkit for his birthday, and I hope, with the help of my issues of EPE, to introduce him and his younger brother to the same wondrous world of electronics – in all its facets. If he or anyone else in my family for that matter ever expresses an interest in electronics magazines I shall be e-mailing EPE Subscriptions again.

I wish you and your staff well for the future, you have had the good sense to move with the times and embrace new technologies, merging them into a well-established publication with great thought and obvious attention to detail, and those are not empty words – I have a shelf here at home which periodically groans under the weight of five or so years worth of EPE mags; and I won't part with them – not for love or money (I shipped more than half of them over here when we emigrated).

Your magazine has in the end been partly responsible for my career change. I've not had reason yet to regret the association, I doubt I ever will. Once again, best wishes.

Mark Lamprecht
via the Net

We thanked Mark for the support that he has given to us over the years and expressed our regrets that, for the moment at least, he will not be rejoining us through subscription (it's sad that he probably will not actually read this edition of Readout).

May his sons one day join us in his place.

Shop Talk

with DAVID BARRINGTON

Some Component Suppliers for EPE Online Constructional Articles

Some Component Suppliers for* EPE Online *Constructional Articles

Antex
Web: **www.antex.co.uk**

Bull Electrical (UK)
Tel: +44 (0) 1273-203500
Email: **sales@bull-electrical.com**
Web: **www.bullnet.co.uk**

CPC Preston (UK)
Tel: +44 (0) 1772-654455

EPE Online Store and Library
Web: **www.epemag.com**

Electromail (UK)
Tel: +44 (0) 1536-204555

Electrovalue (UK)
Tel: +44 (0) 1784-433604
E-mail: **evalue@compuserve.com**

ESR (UK)
Tel: +44 (0) 191-2514363
Fax: +44 (0) 191-2522296
Email: **sales@esr.co.uk**
Web: **www.esr.co.uk**

Farnell (UK)
Tel: +44 (0) 113-263-6311
Web: **www.farnell.com**

Gothic Crellon (UK)
Tel: +44 (0) 1743-788878

Greenweld (UK)
Fax: +44 (0) 1992-613020
Email: **greenweld@aol.com**
Web: **www.greenweld.co.uk**

Maplin (UK)
Web: **www.maplin.co.uk**

Magenta Electronics (UK)
Tel: +44 (0) 1283-565435
Email: **sales@magenta2000.co.uk**
Web: **www.magenta2000.co.uk**

Microchip
Web: **www.microchip.com**

Rapid Electronics (UK)
Tel: +44 (0) 1206-751166

RF Solutions (UK)
Tel: +44 (0) 1273-488880
Web: **www.rfsolution.co.uk**

RS (Radio Spares) (UK)
Web: **www.rswww.com**

Speak & Co. Ltd.
Tel: +44 (0) 1873-811281

Atmospheric Electricity Detector

There are one or two elusive components called for in the *Atmospheric Electricity Detector* that need our special attention.

We are not too sure about suppliers or alternatives for the Siemens B64290 series of toroid ferrite ring cores, so we shall stick with the one used by the author. This was purchased from ElectroValue and you must quote the full code B64290K618X830 when ordering. The specification for this 25mm (O/D)/15mm (I/D) core is 7000AL.

The two ICs should not be quite so difficult to find. The TBA820M power opamp is listed by Cricklewood (Tel: +44 (0) 181-452-0161, Fax: +44 (0) 181-208-1441) and Electromail (code 302-491). The latter company also supplied the AD795 opamp (code 169-091) and the 100 megohm resistor (code 247-7834).

You must specify that you need an insulated (plastic body) chassis mounting coaxial socket when ordering this part. These should be generally available.

Finally, for those readers particularly interested in this fascinating subject, this equipment is referred to on the author's web site under *Atmospheric Electricity* and is kept updated: **http://members.tripod.co.uk/GarwellK**. Also, the author's E-mail address is: **kgarwell@hotmail.com**

Canute Tide Predictor

The alphanumeric 2-line 16-character liquid crystal display module used in the prototype was originally purchased from Magenta Electronics. This comes complete with a connector and we understand they still have stocks. Other component suppliers will no doubt be able to offer something similar.

The orange plastic box is the same one as used in the Micro-PICscope (April '00 issue) and was ordered from Electromail (code 281-6841).

For those readers unable to program their own PICs, a ready-programmed PIC16F876 can be purchased from Magenta (see above) for the inclusive price of 10 UK pounds (overseas readers add 1 UK pound for postage). Software for the Canute Tide Predictor is available for free download from the *EPE Online Library*. The software is written in TASM.

Although the designer used a PIC16F876, this was because he had them to hand. The PIC16F873 may be used

instead. The small printed circuit board is available from the *EPE Online Store* (code 7000267).

Automatic Nightlight

Most of the components for the Automatic Nightlight, this month's Starter Project, should be stocked as "shelf" items by our regular component advertisers. for instance, the cased, low-profile, piezoelectric sounder disc, used as the "microphone", is widely stocked and should cause no purchasing problems.

Timing capacitor C2 must be a good quality (new) component if the unit is to function properly. Using a good quality electrolytic should produce good results, or using a tantalum type would be ideal.

It is important to use a low-power version of the 555 timer IC here because the unit is likely to be left switched on for long periods of time and we do not want to run down the batteries too quickly. The specified TS555CN or the TLC555CP timer ICs are fairly popular devices and should be obtainable from your usual source.

If small children are involved in using the unit, another serious consideration is whether to protect the protruding bulb from possible breakage by covering it with a translucent "dome" or cover. You could try adapting a battery-operated cupboard light, such as the one sold by Maplin (code KR34M).

Multi-Channel Transmission System – Part 2

The 600 ohm 1:1 line-matching transformer used in the Interface Module of the Multi-Channel Transmission System is an RS component and can be purchased through their mail order outlet Electromail (code 208-822).

Any readers experiencing problems finding the AD8532 CMOS dual opamp should note that the one in the model came from Maplin (code OA16S). To keep prices down, the Interface PCB is part of a three-board set and is available from the *EPE Online Store*.

The author is able to supply ready-programmed PIC16F84s for the system. you will need to order at least two microcontrollers, one Transmitter (Tx) and one Receiver (Rx). We understand that the first two will cost 6 UK pounds each and any additional PICs 5 UK pounds each if ordered at the same time, inclusive of postage (overseas add 1 UK pound per order for postage). Orders should be sent to: Andy Flind, 22 Holway Hill, Taunton, Somerset, TA1 2HB, UK. Payments should be made out to A. Flind. For those who wish to program their own PICs, the software is available for free download from the *EPE Online Library*.

Teach-In 2000

No additional components are called for in this month's installment of the *Teach-In 2000* series. For details of special packs readers should contact:

ESR Electronic Components – Hardware/Tools and Components Pack.

Magenta Electronics – Multimeter and components, Kit 879.

FML Electronics (Tel: +44 (0) 1677-425840) – Basic component sets.

N. R. Bardwell (Tel: +44 (0) 114 255-2886) – Digital Multimeter special offer.

PLEASE TAKE NOTE: *High Performance Regenerative Receiver March/April '00*

It has been reported that some specimens of the 2N3819 FET performed badly or not at all. The author advises that this can be cured by increasing the value of resistor R5 to 15 kilohms (15k).